DOE/EIS-0026-DS

DRAFT SUPPLEMENT
ENVIRONMENTAL IMPACT STATEMENT

Waste Isolation Pilot Plant

Volume 1 of 2

April 1989

U.S. DEPARTMENT OF ENERGY
Assistant Secretary for Defense Programs

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Washington, D.C. 20585

THIS DRAFT SEIS SHOULD BE SAVED BECAUSE PORTIONS THAT ARE NOT SIGNIFICANTLY REVISED WILL NOT BE REPRINTED IN THE FINAL SEIS

COVER SHEET

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CONTACT: For further information, contact:

1) W. John Arthur III, Project Manager
WIPP Supplemental Environmental Impact Statement Office
6301 Indian School Road NE, 7th Floor
Albuquerque, New Mexico 87110
(505) 889-3038

2) Carol Borgstrom, Director
Office of NEPA Project Assistance
Office of the Assistant Secretary for Environment, Safety and Health
U.S. Department of Energy
Room 3E-080, Forrestal Building
1000 Independence Avenue SW
Washington, D.C. 20585
(202) 586-4600

3) William Dennison
Acting Assistant General Counsel for Environment
U.S. Department of Energy
Room 6A-113, Forrestal Building
1000 Independence Avenue SW
Washington, D.C. 20585
(202) 586-6947

ABSTRACT: In 1980, the DOE published the Final Environmental Impact Statement (FEIS) for the WIPP. This FEIS analyzed and compared the environmental impacts of various alternatives for demonstrating the safe disposal of transuranic (TRU) radioactive wastes resulting from DOE national defense related activities. Based on the environmental analyses in the FEIS, the DOE published a Record of Decision in 1981 to proceed with the phased development of the WIPP in southeastern New Mexico as authorized by the Congress in Public Law 96-164.

Since publication of the FEIS, new geological and hydrological information has led to changes in the understanding of the hydrogeological

characteristics of the WIPP site as they relate to the long-term performance of the underground waste repository. In addition, there have been changes in the information and assumptions used to analyze the environmental impacts in the FEIS. These changes include: 1) analyses of certain additional DOE generator and/or storage sites as potential contributors to the WIPP waste inventory, 2) changes in the composition of the TRU waste inventory, 3) consideration of the hazardous chemical constituents in TRU wastes, 4) modification and refinement of the system for the transportation of TRU wastes to the WIPP, and 5) addition of the Test Phase.

The purpose of this SEIS is to update the environmental record established in 1980 by evaluating the environmental impacts associated with new information, new circumstances, and proposal modifications. This SEIS evaluates and compares the proposed action and two alternatives for demonstrating the safe disposal of TRU wastes:

The proposed action is to operate the WIPP under a "Test Phase" for approximately five years during which time certain tests and operational demonstrations would be carried out. The tests would be conducted to reduce uncertainties associated with the prediction of natural processes that might affect long-term performance of the underground waste repository. Results of these tests would be used to assess the ability of the WIPP to meet applicable federal standards for the long-term protection of the public and the environment. The operational demonstrations would be conducted to show the ability of the TRU waste management system to certify, package, transport, and emplace TRU wastes in the WIPP safely and efficiently. Upon completion of the Test Phase, the DOE would determine, based on a performance assessment, whether the WIPP would comply with U.S. Environmental Protection Agency (EPA) standards for the long-term disposal of TRU wastes (i.e., 40 CFR Part 191, Subpart B). If there is a determination of compliance, the WIPP would enter a permanent disposal phase of approximately 20 years to demonstrate the safe disposal of TRU wastes. After completion of waste emplacement, the surface facilities would be decommissioned, and the WIPP underground facilities would serve as a permanent radioactive waste repository.

The first alternative, no action, is similar to the no action alternative discussed in the 1980 FEIS. Under this alternative, TRU wastes would continue to be stored at the various generator and storage sites, while the WIPP facility would be decommissioned and potentially put to other uses.

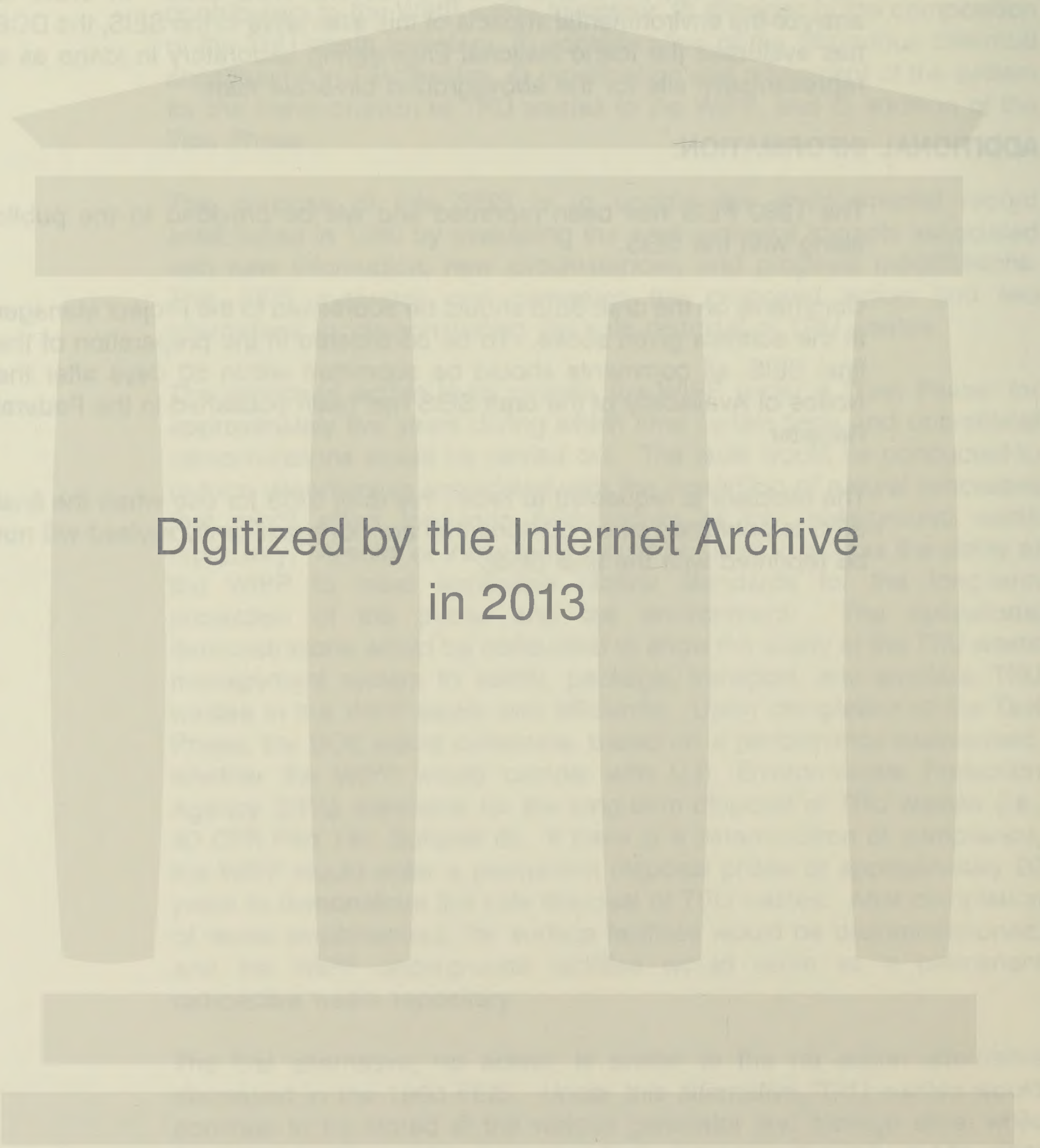
The second alternative to the proposed action is to delay emplacement of TRU wastes in the WIPP underground until a determination has been made of compliance with EPA standards for TRU waste disposal (i.e., 40 CFR Part 191, Subpart B). The DOE has determined that bin-scale tests could be conducted outside the WIPP underground facilities in a specially designed, aboveground facility. This alternative has many implications including delays in both the operational demonstrations and room-scale tests, and the lack of room-scale test data for the compliance demonstration, a temporary mothballing of the WIPP facilities. This is true in any case. The specialized facility for aboveground bin-scale tests could be constructed at any one of several DOE sites. In order to analyze the environmental impacts of this alternative in the SEIS, the DOE has evaluated the Idaho National Engineering Laboratory in Idaho as a representative site for the aboveground bin-scale tests.

ADDITIONAL INFORMATION:

The 1980 FEIS has been reprinted and will be provided to the public along with the SEIS.

Comments on the draft SEIS should be addressed to the Project Manager at the address given above. To be considered in the preparation of the final SEIS, all comments should be submitted within 60 days after the Notice of Availability of the draft SEIS has been published in the Federal Register.

The recipient is requested to retain this draft SEIS for use when the final SEIS is published since portions that are not significantly revised will not be reprinted with the final SEIS.



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SUMMARY

PURPOSE AND NEED

The U.S. Department of Energy (DOE) has prepared this supplement to the 1980 Final Environmental Impact Statement (FEIS) for the Waste Isolation Pilot Plant (WIPP) in order to assess the environmental impacts that may occur from the continued development of the WIPP as a mined geologic repository for transuranic (TRU) waste. A permanent repository is needed for the disposal of TRU wastes being generated and stored at several DOE facilities around the country. Transuranic wastes are materials contaminated with alpha-emitting radionuclides that are heavier than uranium with concentrations higher than 100 nanocuries per gram and half-lives longer than 20 years. Since 1970, these wastes have been stored separately from other radioactive wastes in a manner that allows them to be retrieved for permanent emplacement in a geologic repository.

The WIPP was authorized by Public Law 96-164 to provide a research and development facility for demonstrating the safe disposal of radioactive wastes produced by national defense activities. The DOE's decision to proceed with the WIPP project at a location in southeastern New Mexico followed a thorough review in accordance with the National Environmental Policy Act (NEPA) and was announced in a Record of Decision (January 1981) selecting Alternative 2 of the FEIS. That alternative called for the phased development of the WIPP, consisting of surface and underground facilities designed to emplace approximately 6.2 million cubic feet (ft^3) of contact-handled (CH) TRU waste and 250,000 ft^3 of remote-handled (RH) TRU waste in a 100-acre mined repository.

The major construction activities at the WIPP are nearly complete; surface facilities are essentially complete, and most of the underground rooms for experimentation and for initial waste emplacement have been excavated. The DOE proposes to start using the WIPP in late 1989 for certain experiments and operational tests during a Test Phase estimated to last approximately five years. These tests would not begin until: 1) the U.S. Nuclear Regulatory Commission (NRC) has certified that the containers to be used for shipping the TRU wastes to the WIPP meet regulatory requirements, 2) the DOE has received the needed authority to withdraw public lands for WIPP use, 3) a preoperational readiness analysis has been completed, and 4) applicable environmental requirements have been satisfied.

Since the publication of the FEIS in October 1980, new data collected at the WIPP have led to changes in the understanding of the hydrogeologic characteristics of the area and their potential implications for the long-term performance of the WIPP. In addition, there have been changes in the FEIS Proposed Action and new regulatory requirements. This supplement to the FEIS (SEIS) evaluates the environmental consequences of the Proposed Action as modified since 1980 in light of new data and assumptions. The principal modifications that are addressed in this SEIS are as follows:

- Changes in waste sources. The 1980 FEIS Proposed Action included only those TRU wastes from the Idaho National Engineering Laboratory and the Rocky Flats Plant. The WIPP is now proposed as a repository for TRU waste from two additional sources: the Savannah River Plant and the Hanford Reservation. Moreover, the DOE may propose that TRU wastes generated by, or stored at, six other facilities be transferred to the WIPP. Appropriate site-specific NEPA documentation would be prepared for such a proposal for the six facilities.

- Changes in the volume of the TRU wastes. In 1980, the DOE expected that approximately 6.2 million ft^3 of CH TRU waste and 250,000 ft^3 of RH TRU waste could be disposed of in the WIPP over the 25-year design life of the facility. Current estimates indicate a smaller volume, approximately 5.6 million ft^3 of CH TRU waste and 93,000 ft^3 of RH TRU waste, are in retrievable storage at 10 generator/storage facilities and/or will be newly generated by these facilities through the year 2013. In this SEIS, impact assessments are based on the projected 1980 design quantities to set an upper limit on the potential impacts of disposal.

- Changes in the composition of the TRU-waste radioactivity inventory. In 1980, high-curie and high-neutron wastes were not considered; the inventory evaluated in this SEIS includes such wastes. Experiments using high-level wastes are no longer proposed for the WIPP.

- Consideration of the hazardous chemicals in the TRU waste. In 1980, the impacts of the hazardous chemical component of TRU waste were not analyzed. In 1987, the DOE decided that wastes containing such chemicals were to be regulated under the Atomic Energy Act and the Resource Conservation and Recovery Act. Impacts associated with the transport, handling, and emplacement of the hazardous waste component of mixed TRU wastes are assessed in this SEIS.

- Changes in the modes of transportation. In the FEIS, it was assumed that 75 percent of the waste shipments to the WIPP would be made by train and 25 percent by truck. This SEIS considers all-truck transport and an alternative "maximum" rail transport mode in which trains are used for transport from eight facilities and trucks are used for transport from the two facilities that have no railheads. The use of all-truck transportation is currently planned; the train option is analyzed as an option in this SEIS in the event it is utilized in the future.

- Changes in waste packages. The design of the package for CH TRU has changed from a Type A (TRUPACT-I) container in 1980 to a Type B (TRUPACT-II) container to be certified by the Nuclear Regulatory Commission.

- Implementation of a Test Phase. Before beginning WIPP disposal operations, the DOE proposes that a Test Phase of approximately five years involving emplacement of a limited volume of TRU waste in the WIPP. The Test Phase would be conducted to gather data in order to assess the long-term performance of the repository and demonstrate safe waste management system operations.

The new information pertains mainly to the geologic and hydrologic systems at the WIPP site and their effect on the long-term performance of the WIPP. The SEIS includes new data indicating that:

- The permeability of the Salado Formation, the geologic formation in which the WIPP underground facilities are located, is lower than previously believed.
- The moisture content of the Salado Formation and the consequent brine inflow is higher than previously believed.
- A higher transmissivity zone is present in the Rustler Formation in the southeastern portion of the WIPP site.
- "Salt creep" (convergence) in the repository occurs faster than previously believed.

At the time of the publication of this draft SEIS, certain regulatory-compliance issues for the WIPP remain unresolved. These include: the status of the standards promulgated by the Environmental Protection Agency (EPA) for the disposal of TRU wastes in 40 CFR Part 191, Subpart B, which was vacated and remanded to the EPA by a U.S. Court of Appeals; procedural issues for NRC certification of the Transuranic Package Transporter (TRUPACT-II); and compliance with the Resource Conservation and Recovery Act (RCRA). Although these standards and requirements provide a framework for the analyses reported in the SEIS, it is not the purpose of the SEIS to resolve these issues or to demonstrate compliance with regulatory requirements.

BACKGROUND

The WIPP site is located in Eddy County in southeastern New Mexico, approximately 26 miles southeast of Carlsbad. It lies on a relatively flat, sparsely inhabited plateau with little surface water and limited land use. The land is owned by the Federal government and administered by the Bureau of Land Management. The land is used mainly for livestock grazing, potash mining, and oil-and-gas exploration and development.

The principal surface structure at the WIPP is the waste handling building, in which TRU wastes would be received, inspected, and moved to a waste handling shaft for transfer underground. The building also contains offices, change rooms, a health- physics laboratory, and equipment for ventilation and filtration. Other surface facilities include a water pumphouse, a sewage-treatment plant, a building for safety and emergency services, a guard and security building, and warehouses.

The constructed underground facilities include four shafts, the waste disposal area, an experimental area, an equipment and maintenance area, and connecting tunnels. These underground facilities were mined in the Salado Formation 2,150 feet beneath the land surface. The waste storage area has been mined in the same design as described in the FEIS, but was reconfigured slightly south of the original location in the Salado Formation. The "room and pillar" arrangement includes two separate mined areas:

- A TRU waste disposal area (100 acres total designed to hold 6.5 million ft^3 of TRU waste). To date, about 15 acres have been mined.
- An experimental area (12 acres) used for repository safety and mine performance studies.

Not all of the waste disposal rooms have been mined. Due to the natural process of salt "creep" which causes eventual room closure, additional waste disposal rooms would be mined immediately in advance of permanent waste emplacement during the Disposal Phase.

The DOE defense-program TRU wastes result primarily from plutonium reprocessing and fabrication, as well as research and development activities at various DOE facilities. The wastes exist in a variety of forms ranging from unprocessed laboratory trash (e.g., tools, glassware, and gloves) to solidified sludges from waste water treatment. TRU wastes are classified, for purposes of acceptability at the WIPP, according to the radiation dose rate at the waste package or container surface.

About 60 percent of these TRU wastes also contain hazardous chemical constituents that were not addressed in the 1980 FEIS. TRU wastes containing hazardous chemical constituents have physical and radiological characteristics similar to those of TRU wastes that do not contain these constituents. A major chemical constituent in TRU waste is lead, which is present predominantly in the form of glove box parts, and lead-lined gloves and aprons. Organic solvents (e.g., methylene chloride, toluene) are present in some waste types and exist primarily as residual quantities from the cleaning of equipment, plastics, and glassware.

Very specific acceptance criteria have been established for waste coming to the WIPP. The criteria govern the physical, radiological, and chemical composition of the wastes to be emplaced in the WIPP, and establish specifications for waste packaging. The DOE established the Waste Acceptance Criteria (WAC) in consideration of the U.S. Department of Transportation (DOT) and U.S. Nuclear Regulatory Commission (NRC) regulations for the safe handling and transport of waste.

The DOE requires that each TRU waste generator develop and implement a program that establishes procedures for waste certification and quality assurance. Each site-specific plan identifies and describes the administrative controls and procedures required to characterize TRU waste, segregate and process waste forms, and package waste in accordance with the WAC.

Procedures for the receipt, emplacement, and retrieval of TRU wastes at the WIPP remain unchanged since publication of the FEIS. The design of the waste handling building provides a multibarrier confinement system that prevents any contaminated airborne particulates from leaving the building. All TRU waste emplacement would be conducted so as to maintain retrievability for a reasonable period.

Decommissioning of the WIPP site would be conducted in a manner that would allow for the safe, permanent disposition of surface and underground facilities consistent with the applicable regulations. Dismantling is currently planned as the method of decommissioning. Usable equipment would be decontaminated and removed; equipment that could not be decontaminated would remain underground. The underground facilities would be filled with salt, and the shafts and boreholes would be sealed and plugged. Surface facilities would be decontaminated and demolished or dismantled; debris would be removed. The WIPP site landscape would be returned as near to its original condition as possible. The WIPP site would be permanently marked with durable monuments, and documents about the WIPP would be maintained in public archives. Administrative controls consistent with the Environmental Protection Agency's (EPA) standards for disposal of radioactive waste, 40 CFR Part 191, Subpart B, would be imposed to minimize human intrusion, and closure and post-closure plans would be prepared and implemented in accordance with the Resource Conservation and Recovery Act (RCRA) regulations (40 CFR Part 265).

The FEIS described precautions, emergency actions, and procedures to be taken in response to radiation-related and other emergencies at the WIPP. Additionally, the FEIS described an emergency preparedness program for transportation-related incidents. Emergency actions and procedures described in the FEIS have been implemented, and drills have been conducted to test response capabilities in a variety of emergency situations.

The transportation emergency preparedness program has also been implemented. Achievements to date include establishing relationships with local, state, and Federal government agencies and Indian tribal governments; conducting an extensive emergency response and preparedness training program; conducting public awareness tours; and establishing a system that will accurately track all TRU waste shipments to the WIPP site. The DOE has reviewed emergency plans from the 23 involved states and has offered assistance in developing emergency plans to communities along the transportation routes.

DESCRIPTION OF ALTERNATIVES

This SEIS presents a Proposed Action, an alternative of No Action, and an Alternative Action of conducting only those tests that can be performed without the emplacement of waste underground until there is a determination of compliance with the EPA standard 40 CFR Part 191, Subpart B. The alternative of either conducting no tests involving wastes or conducting tests with simulated, nonradioactive wastes was considered and rejected as unreasonable because it would not provide sufficient data for assessing compliance with applicable standards.

PROPOSED ACTION

The Proposed Action is to proceed with a phased approach to determine whether the WIPP should become a repository for the disposal of TRU waste. A phased decision-making process relative to construction and operation of the WIPP has been pursued since the TRU waste disposal program's inception. Generally, this process began with site selection and characterization; proceeded through site design and validation to construction; would continue, if appropriate, with a Test Phase; and conclude, if appropriate, with a Disposal Phase.

Pursuant to this phased approach, the DOE proposes the implementation of a Test Phase. The Test Phase has two distinct parts: 1) the Integrated Operations Demonstration, and 2) Performance Assessment. The DOE proposes to initiate the Test Phase in the fall of 1989.

The Integrated Operations Demonstration is intended to demonstrate the ability of the waste management system to safely and efficiently certify, package, transport, and emplace waste in the WIPP. Operations testing and monitoring would be performed at the waste storage and generator facilities during waste transportation to the WIPP, and at the WIPP.

The Performance Assessment is the process of determining how an engineered facility will behave relative to a predetermined set of criteria or expectations. For the WIPP, the Performance Assessment is intended to show whether the repository meets the standards promulgated by the EPA in 40 CFR Part 191, Subpart B. These standards were vacated and remanded to the EPA by a Federal Court of Appeals and are not expected to be repromulgated until 1991 or 1992. However, in the interim, the DOE has agreed with the State of New Mexico to proceed with the Test Phase and planning for long-term waste emplacement as if these standards were still in effect.

The proposed Test Phase includes bin-scale tests and room-scale tests to provide data for the Performance Assessment calculation process. The bin-scale tests are being designed to provide information concerning gas generation, gas composition, and gas depletion rates as well as radiochemical source term data from actual CH TRU waste. CH TRU waste would be mixed in specially designed bins with backfill, brine, and salt to simulate conditions to which the waste would be exposed within the repository. The waste used would be representative of the TRU waste inventory. Room-scale tests would provide additional confidence in the Performance Assessment analyses described earlier. Because of the potential uncertainties inherent in extrapolating laboratory or even bin-scale results to the full-scale repository, room-scale tests are proposed within the WIPP repository to validate gas generation models and predict impacts for realistic waste inventory emplacements. In addition to reducing uncertainties associated with scaling results from smaller-scale experiments, room-scale tests would also be conducted with wastes modified to simulate the impacts of the actual repository environment on the long-term degradation behavior of the wastes.

At the conclusion of the Test Phase, the DOE would decide whether, based upon Performance Assessment analyses, the WIPP would comply with 40 CFR Part 191, Subpart B. If there was a determination of compliance, the WIPP would move into the

Disposal Phase. If there was a determination of noncompliance with 40 CFR Part 191, Subpart B, a number of options (e.g., engineered barriers, waste treatment) would be considered and the required NEPA documentation would be prepared.

NO ACTION ALTERNATIVE

This SEIS also provides environmental analyses of two alternatives to the Proposed Action. The first alternative, No Action, is similar to the No Action Alternative discussed in the 1980 FEIS, with the additional implications of no action for the Savannah River Plant and Hanford Reservation facilities. TRU wastes would continue to be generated and placed in retrievable storage. The WIPP would be decommissioned and potentially put to other uses. The potential long-term hazards to public health and the environment would remain as a consequence of long-term use of facilities that were designed only for interim storage. The No Action Alternative may have adverse impacts on nuclear weapons programs and maintenance.

ALTERNATIVE ACTION

This SEIS also evaluates an alternative to the Proposed Action that would allow no emplacement of TRU waste in the WIPP underground until a determination has been made of compliance with the EPA standards in 40 CFR Part 191, Subpart B. Of those components of the Test Phase that are proposed for the WIPP underground, only the bin-scale tests portion could reasonably be conducted at a location other than the WIPP underground. Thus, this alternative is essentially the same as the Proposed Action except for changes in the Test Phase. These tests would need to be conducted in a specially engineered aboveground facility that would be constructed for this purpose.

The objective of the bin-scale tests under this alternative is identical with that described under the Proposed Action. Bin-scale tests for this alternative could be accomplished at any one of several DOE site locations and would require the construction of a specialized facility to perform the tests. The Idaho National Engineering Laboratory was chosen as a representative site for purposes of analyzing impacts that would generally be representative of impacts associated with bin-scale tests aboveground for any of these alternative locations. (It is not the DOE's intent to propose the Idaho National Engineering Laboratory as the site for bin-scale tests, but simply to use it to illustrate representative levels of impact.)

Since the room-scale tests could not be performed practically or usefully at a location other than the WIPP underground, the results of the room-scale tests would not be available to increase confidence regarding extrapolation of laboratory and bin-scale results to a full-scale representative repository loading. Therefore, the uncertainty in the Performance Assessment would be greater than for the Proposed Action. If the uncertainty in the Performance Assessment should be unacceptable, the DOE would evaluate further courses of action.

Under the Alternative Action, the Integrated Operations Demonstration portion of the WIPP Test Phase would not be conducted prior to the completion of the compliance determination. This alternative would also delay the movement of a certain amount of newly-generated TRU waste from the Rocky Flats Plant and stored waste from the Idaho

TABLE S-1 Summary of environmental consequences

Environmental component	Proposed Action	No Action	Alternative Action: No TRU wastes in WIPP until compliance with disposal standards demonstrated: bin-scale tests at other DOE facility
Vegetation and Wildlife	Same or less than those described in 1980 FEIS[a].	Temporary disturbance of wildlife and vegetation during decommissioning of WIPP.	During Test Phase, less than 0.25 acre of land disturbance at other DOE facility; very little effect on vegetation and wildlife; Disposal Phase consequences would be the same as for the Proposed Action.
Socioeconomics	Maximum direct and indirect employment of 1610 during Disposal Phase; total economic impact of $4.3 billion through decommissioning.	Reduction in WIPP employment with corresponding economic impact to regional economy; approximately $75 million would be spent for WIPP closure; approximately $1 billion will have been spent without waste disposal.	Construction costs of $3.5 million for test facility; maximum direct employment of 11 at other DOE facility during bin-scale tests with no appreciable economic impact; maximum reduction in WIPP employment of 145 during bin-scale tests with corresponding economic impacts; additional costs of $19 to $121 million because of temporary delay to WIPP operation and subsequent start-up costs.
Cultural Resources	No additional impacts anticipated.	No impacts anticipated.	No impacts anticipated.
Land Use	Same as those described in 1980 FEIS except that approximately 10,000 acres would be available for unrestricted use[b]; approximately 50 million tons of potash resources available for extraction.	DOE-controlled lands would be returned to previous status and use; hydrocarbon and potash resources available for extraction.	No appreciable impacts at other DOE facility for bin-scale tests; same as those for Proposed Action at WIPP during the Disposal Phase.
Air Quality	Same as those described in 1980 FEIS[c].	Temporary decline in air quality during decommissioning of WIPP.	Temporary decline in air quality at existing DOE facility during facility construction for bin-scale tests; release of small amounts of radionuclides during bin-scale tests; same as those for the Proposed Action at WIPP during the Disposal Phase.
Waste Retrieval from Idaho National Engineering Laboratory	Routine operational doses within DOE standards; population doses from accidental release would be significantly less than background; no projected fatalities due to latent cancers.	No waste retrieval would occur.	For the Test Phase, impacts associated with waste retrieval to support bin-scale tests will be less than for Proposed Action due to lower volume retrieved; impacts during the Disposal Phase would be the same as described in the Proposed Action.

TABLE S-1 Continued

Environmental component	Proposed Action	No Action	Alternative Action: No TRU wastes in WIPP until compliance with disposal standards demonstrated; bin-scale tests at other DOE facility
<u>Transportation</u>			
I. Accident related fatalities/injuries			
Truck	8.3 fatalities and 106 injuries	Minimal risk[d]	8.3 fatalities and 106 injuries
Rail	3.0 fatalities and 34 injuries	Minimal risk	3.0 fatalities and 34 injuries
II. Radiological Risk to Public[e]			
Routine Transport			
			$^{-2}$ excess latent cancer fatalities
			$^{-2}$ excess latent cancer fatalities
			$^{-3}$ excess latent cancer fatalities
			$^{-3}$ excess latent cancer fatalities
III. Chemical Risks to Public[g]			
Routine Transport			
Truck	No exposure	Minimal risk	No exposure
Rail	No exposure	Minimal risk	No exposure
Accident Conditions			
Truck	Minimal exposure	Minimal risk	Minimal exposure
Rail	Minimal exposure	Minimal risk	Minimal exposure

Summary	S-9	Table 2-1	(1) Proposed Action column, II. Radiological Risk to Public, Routine Transport, Rail, 1.1×10^{-2}, should read 1.2×10^{-2}. (2) Proposed Action column, II. Radiological Risk to Public, Accident Conditions, Rail, 2.3×10^{-3}, should read 1.3×10^{-3}.

TABLE S-1 Continued

Environmental component	Proposed Action	No Action	Alternative Action: No TRU wastes in WIPP until compliance with disposal standards demonstrated; bin-scale tests at other DOE facility
<u>Consequences of Operations/Retrieval</u>			
I. Public Health (Routine Operations)			
Radiological risks[e]	2.5×10^{-5} excess latent cancer fatalities	Minimal short-term risk[j]	2.6×10^{-5} excess latent cancer fatalities
Carcinogenic chemical risks[f]	6.9×10^{-10} incremental lifetime cancer risks	Minimal short-term risk	6.9×10^{-10} incremental lifetime cancer risks
Noncarcinogenic chemical risks[g]	9.0×10^{-8} (hazard indices)	Minimal short-term risk	9.0×10^{-8} (hazard indices)
Public Health (Operational Accidents)			
Radiological risks[h]	3.1×10^{-4} excess latent cancer fatalities	Minimal short-term risk	3.1×10^{-4} excess latent cancer fatalities
Carcinogenic chemical risks[f,i]	Minimal risk	Minimal short-term risk	Minimal risk
Noncarcinogenic chemical risks[g,i]	Minimal risk	Minimal short-term risk	Minimal risk

TABLE S-1 Continued

Environmental component	Proposed Action	No Action	Alternative Action: No TRU wastes in WIPP until compliance with disposal standards demonstrated; bin-scale tests at other DOE facility
<u>Consequences of Operations/Retrieval Continued</u>			
II. Worker Health (Routine Operation)			
Radiological risk	5.3×10^{-3} excess latent cancer fatalities	Minimal short-term risk[j]	5.8×10^{-3} excess latent cancer fatalities
Carcinogenic chemical risks	1.6×10^{-6} incremental lifetime cancer risks	Minimal short-term risk	1.6×10^{-6} incremental lifetime cancer risks
Noncarcinogenic chemical risks[g]	2.3×10^{-4} (hazard indices)	Minimal short-term risk	2.3×10^{-4} (hazard indices)
Worker Health (Operational Accidents)			
Radiological risks[h]	2.6×10^{-3} risk of excess latent cancer fatalities	Minimal short-term risk	2.6×10^{-3} risk of excess latent cancer fatalities
Carcinogenic chemical risks[f]	1.7×10^{-4} incremental lifetime cancer risks	Minimal short-term risk	1.7×10^{-4} incremental lifetime cancer risks
Noncarcinogenic chemical risks[g]	1.1×10^{-4} (hazard indices)	Minimal short-term risk	1.1×10^{-4} (hazard indices)

TABLE S-1 Continued

Environmental component	Proposed Action	No Action	Alternative Action: No TRU wastes in WIPP until compliance with disposal standards demonstrated; bin-scale tests at other DOE facility
Long-term Radiological Impacts		No permanent repository selected; wastes remain in temporary storage; off-site exposures could result from various natural disruptive events and/or human intrusion[j]	
Case I: undisturbed repository (expected and degraded conditions case)	no resulting exposure	NA[l]	same as Proposed Action
Case II: repository intrusion			
• Drill crew: maximum exposure to worker	0.077 mrem	NA	same as Proposed Action
• Nearby ranch (from resuspension of dried mud pit particles)	0.766 mrem (50 year committed dose equivalent per year of exposure)[k]	NA	same as Proposed Action
• Human consumption of contaminated beef			
• Expected case (Case II A)	0.0002 mrem (50 year committed dose equivalent per year of exposure)	NA	same as Proposed Action
• Degraded conditions with no mitigation (Case II C)	129 mrem (50 year committed dose equivalent per year of exposure)	NA	same as Proposed Action
• Degraded conditions with mitigation (Cases II B and II D)	0.9 to 72 mrem (50 year committed dose equivalent per year of exposure)	NA	same as Proposed Action

TABLE S-1 Concluded

Environmental component	Proposed Action	No Action	Alternative Action: No TRU wastes in WIPP until compliance with disposal standards demonstrated

[a] FEIS Subsections 9.2.1 and 9.3.1.

[b] FEIS Subsection 9.4.5.

[c] FEIS Subsection 9.3.1.

[d] No Action and decommissioning of the WIPP site would result in minor impacts accociated with the removal of certain equipment and supplies to other, unspecified locations. Additionally under the No Action alternative, no waste transport to WIPP would occur. Consequences of waste transport to interim storage facilities would continue.

[e] Radiological risks are expressed as excess latent cancer fatalities to the total population at risk.

[f] Incremental lifetime cancer risk (also referred to as excess cancer risk) is defined as the estimated increased risk that occurs over an assumed average lifespan of 70 years as the result of exposure to a specific known carcinogen. Thus, an incremental lifetime cancer risk of one in a million (1×10^{-6}) may be interpreted as an increase in the baseline cancer incidence from 280,000 per million population to 280,001 per million population.

[g] Risks associated with noncarcinogens are presented in terms of hazard indices. The estimated daily intakes of the various receptors are divided by the acceptable reference levels. Hazard indices of less than unity indicate acceptable levels of exposure. The numbers shown represent the maximum exposure values derived for all chemicals evaluated.

[h] For operational accidents, radiological risks are for the maximally exposed individual.

[i] For each accident event, the maximum hazard index is at least three orders of magnitude less than unity. If hazardous chemicals were to be transported to the hypothetical receptor at the site boundary as a result of atmospheric dispersion of any of the on-site accident releases, the dilution in the vastly increased air volume (coupled with the increased diffusion) would produce expected hazard index ranges which had maximum values even less than the already insignificant hazard indices estimated for the on-site occupation receptor.

[j] Leaving wastes in interim storage at generator/storage facilities, would require site specific radiological and chemical impact analyses. Refer to text for details known to date.

[k] 50-year committed dose equivalent.

[l] NA = not applicable, since under No Action the WIPP would not be used for TRU waste disposal; therefore, no repository release or subsequent exposure could occur

National Engineering Laboratory to the WIPP. This newly-generated waste from the Rocky Flats Plant would either have to be shipped to the Idaho National Engineering Laboratory or would have to be shipped to another location identified for interim storage. All other actions as described in the Proposed Action could remain the same under this alternative, although selected activities may be delayed as described.

ALTERNATIVES CONSIDERED BUT REJECTED

The DOE also considered the possibility of performing experiments in support of the Performance Assessment with simulated, nonradioactive waste. While this alternative would avoid potential effects associated with the use of radioactive waste during the Test Phase, it was determined to be unreasonable. For the confident evaluation of the effect of gases on the long-term behavior of the repository, it is necessary to use actual TRU (radioactive) waste to obtain relevant and sufficient data. Several different types of data regarding the behavior of TRU wastes are required. These include information about gas generation, gas speciation, and gas depletion rates as a function of time and of various waste conditions. The impacts of radiolytic, bacterial, and chemical corrosion degradation mechanisms can only be adequately analyzed in tests that use actual radioactive TRU waste. Finally, the synergisms, or complex interactions, between various ongoing in situ processes can only be effectively analyzed when actual TRU wastes are used.

A variation of this alternative would be to proceed with the Performance Assessment with no tests using waste in the WIPP and no new construction for aboveground tests. This alternative is unreasonable for the reasons given above with respect to using simulated waste. In both cases, the DOE would not have sufficient data for conducting a Performance Assessment that would provide a basis for determining compliance with 40 CFR Part 191, Subpart B.

EXISTING ENVIRONMENT

The existing environment at the WIPP site is generally the same as described in the 1980 FEIS. However, the WIPP construction activities and studies conducted since the 1980 FEIS have generated some new environmental information for the WIPP site. These studies include the baseline environmental monitoring programs, raptor research and management program, and the Research and Development (R&D) Program that was initiated for the WIPP in the 1970s.

The DOE believes that the actions proposed in this SEIS would have no impact on any threatened or endangered species because these actions involve no new critical habitat or ground disturbance. Since publication of the FEIS, the economy of the WIPP site area has been depressed by declines in the oil, gas, and mining industries. Land use surrounding the WIPP site has not changed, but the release of approximately 11,000 acres in Control Zone IV would allow mineral exploration and development and permanent habitation where those activities were previously restricted. The WIPP environmental monitoring programs have revealed that air quality in the area of the WIPP site generally meets State and Federal standards. Also, radionuclide concentrations in soil, surface water, sediment samples, and key organisms fall within expected ranges and do not indicate any unexpected environmental concentrations.

ENVIRONMENTAL CONSEQUENCES

The environmental consequences presented in this SEIS are based on conservative assumptions and impact assessment methods designed to bound the potential consequences of WIPP operations. Impacts are presented for several components of WIPP operation: transportation, waste emplacement and retrieval, and long-term performance of the disposal facility. Table S-1 provides a summary of environmental consequences for the Proposed Action, No Action, and Alternative Action.

TRANSPORTATION

Transportation impacts were assessed for potential TRU waste shipments from the ten generator and storage facilities. Impacts were assessed for waste transport by truck (34,144 shipments) and by rail (18,467 shipments) for the proposed 25-year combined Test Phase and Disposal Phase at the WIPP.

Incident-Free Conditions: For the Proposed Action, the annual cumulative radiological exposure (person-rem) to the public for all TRU shipments by truck is estimated to be 59 and 43 for transport by truck, and maximum rail, respectively. The resultant

x 10^{-2} and 1.3 x 10^{-2} excess latent cancer fatalities by truck and rail transport, respectively.

Summary	**S-15**	**fourth ¶**	**Fifth line, 1.1 x 10^{-2}, should read 1.2 x 10^{-2}.**

Since the TRUPACT-II is a non-vented package, hazardous chemical components of the TRU waste are not expected to be released under incident-free conditions. Therefore, no additional impacts are predicted because of these components.

Accident Conditions: The transportation analysis presented in this SEIS is based upon the best available nationwide average truck accident data (1.1 x 10^{-6} accidents per kilometer). Current state-specific highway data obtained during the SEIS preparation are comparable.

For the truck shipment of TRU waste, the total estimated risks for the projected 25-year Test and Disposal Phases are 8.3 fatalities and 106 injuries for the Proposed Action. The total estimated risks for rail transport for the Proposed Action are 3.0 fatalities and 34 injuries. Estimated transportation risks for the Alternative Action are identical to the Proposed Action.

The RADTRAN-II model was used to estimate the radiological risk to the public for TRU waste transportation related accidents. Radiological risks to the public were categorized based upon a range of accident scenarios and their probability of occurance. In addition, a "bounding case" scenario based on conservative assumptions was developed for the SEIS, and was used to calculate the impact of a very severe accident.

When considering the "bounding case" accident scenario, a cumulative effective 50-year population dose commitment of 1,240 person-rem and a maximum individual committed effective dose equivalent of 0.49 rem was estimated. The average individual committed effective dose equivalent was 0.08 rem. No premature fatalities would be expected from these exposures. Based on a rate of 2.8 excess latent cancer fatalities per 10,000 person-rem, 0.35 excess latent cancer fatalities would be expected in the population exposed to the "bounding case" transportation accident.

No adverse human health effects are expected from the exposure to the hazardous chemical constituents of TRU waste released during a transportation accident. The two primary reasons for the lack of adverse impacts are the low initial concentrations of chemicals within the waste containers, and the physical form of the waste, which restricts the concentrations available for release.

CONSEQUENCES OF OPERATIONS/RETRIEVAL

The risk assessment for the Proposed Action estimates potential radiological and hazardous chemical releases during routine WIPP operations and resulting from postulated accident scenarios. Estimated impacts from accidents are the same for the Proposed Action and Alternative Action. The impacts of these releases on occupational workers and the public are evaluated in terms of exposures and health risks. To compensate for uncertainties, the risk assessments are biased toward conservatism (i.e., they tend to overestimate the risk).

Routine Operations: The annual occupational excess risks (radiological) resulting

Summary	S-16	fourth ¶	Last line, "2.6 x 10^{-5} (Alternative Action) excess latent cancer fatalities are 6.9 x 10^{-10}," should read, "2.6 x 10^{-5} (Alternative Action) excess latent cancer fatalities."

The risk to nearby residents of the WIPP was evaluated for releases of hazardous chemicals during routine operations. The chemicals considered were carbon tetrachloride, methylene chloride, and trichloroethylene. The estimated excess cancer risk attributable to releases during the Proposed Action and Alternative Action.

Both aboveground and underground occupational exposures to carbon tetrachloride, methylene chloride, and trichloroethylene were estimated. The underground occupational exposure provided the highest excess total cancer risk for these three chemicals and was estimated to be 1.6 x 10^{-6}.

Accident Conditions: The health risks associated with the radiological exposure to an individual at the nearest residence following a severe postulated accident at the WIPP is about 3.1 in ten thousand (3.1 x 10^{-4}) for both the Proposed and Alternative Actions. When considering the HEPA filtration, the risk drops by a factor of one million. During disposal and given a severe postulated accident, individuals in the WIPP work force would incur an estimated excess risk of up to 26 chances in 10,000 of contracting a fatal cancer.

The maximum predicted hazardous chemical intake by a worker was approximately four orders of magnitude below the Threshold Limit Value-based estimated intake and three orders of magnitude below the Immediate Danger to Life and Health-based estimated intake. Exposures to the public from onsite accidents would be less than those to a worker, and therefore are also well below health protection reference levels.

LONG-TERM PERFORMANCE

Human exposure: This SEIS evaluates two basic long-term release scenarios that are expected to bound potential impacts that could result from the long term disposal of TRU wastes at the WIPP. The first scenario (Case I) examines the long-term performance of an undisturbed repository. The second scenario (Case II) examines a hypothetical intrusion into the repository by an exploratory borehole passing through the repository into a pressurized brine reservoir below. Two variations of Case I and four variations of Case II are examined. Cases IA and IIA are "base-case" scenarios that use expected, mid-range values for the various input parameters. In Cases IB, IIB, IIC, and IID, the flow and transport properties are intentionally degraded (i.e., the transport of potential contaminants is greatly increased), in order to evaluate long-term repository behavior under more severe, less probable conditions. Additionally, in Cases IB, IIB, and IID, potential treatments/engineering modifications are postulated (e.g., precompaction of waste) to at least partially mitigate the effects of this behavior. Therefore, these scenarios predict the undisturbed and disturbed behavior of the repository, under both expected conditions and under more pessimistic conditions.

Radiation exposure and lead intake for the most exposed individual are calculated. Some exposures are due to contaminated drilling mud and cuttings brought to the surface, while others result from contaminants transported by groundwater in the Culebra aquifer to a hypothetical livestock well approximately 3 mi (5km) south of the center of the WIPP site. (The stock well is assumed to be at the nearest point downgradient where water usable by livestock might be found. The water at this well site is too saline for human consumption.) Human exposures are quantified based on the maximum radionuclide and lead concentrations that may occur within 10,000 years at the stock well.

In the two versions of Case I (IA and IB) that treat the undisturbed repository, no radionuclides reach the groundwater or the surface within 10,000 years; therefore, there is no potential for human exposure within that time.

In all Case II intrusion scenarios, radioactive material and lead are brought to the surface immediately. Resultant exposures to the drill crew and a nearby downwind ranch family are about two orders of magnitude below usual guidelines (e.g., 100 mrem/yr general dose limit established by the International Commission on Radiation Protection). The expected behavior of the disturbed repository (Case IIA) is well within these guidelines and natural background radiation exposure levels. If, however, the groundwater flow parameters are considerably poorer than expected (Cases IIB and IIC), the doses predicted are at or above the radiation guidelines. The highest total dose would occur in Case IIC in which transport parameters are degraded and no engineering modifications are postulated to minimize the impacts. The Case IIC peak

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Routine Operations: The annual occupational excess risks (radiological) resulting from routine operations for the Proposed Action and Alternative Action are estimated to be about 5.3×10^{-3} and 5.8×10^{-3} excess latent cancer fatalities, respectively. Radiological risk to the public was estimated to be 2.5×10^{-5} (Proposed Action) and 2.6×10^{-5} (Alternative Action) excess latent cancer fatalities are 6.9×10^{-10}.

The risk to nearby residents of the WIPP was evaluated for releases of hazardous chemicals during routine operations. The chemicals considered were carbon tetrachloride, methylene chloride, and trichloroethylene. The estimated excess cancer risk attributable to releases during the Proposed Action and Alternative Action.

Both aboveground and underground occupational exposures to carbon tetrachloride, methylene chloride, and trichloroethylene were estimated. The underground occupational exposure provided the highest excess total cancer risk for these three chemicals and was estimated to be 1.6×10^{-6}.

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Radiation exposure and lead intake for the most exposed individual are calculated. Some exposures are due to contaminated drilling mud and cuttings brought to the surface, while others result from contaminants transported by groundwater in the Culebra aquifer to a hypothetical livestock well approximately 3 mi (5km) south of the center of the WIPP site. (The stock well is assumed to be at the nearest point downgradient where water usable by livestock might be found. The water at this well site is too saline for human consumption.) Human exposures are quantified based on the maximum radionuclide and lead concentrations that may occur within 10,000 years at the stock well.

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In all Case II intrusion scenarios, radioactive material and lead are brought to the surface immediately. Resultant exposures to the drill crew and a nearby downwind ranch family are about two orders of magnitude below usual guidelines (e.g., 100 mrem/yr general dose limit established by the International Commission on Radiation Protection). The expected behavior of the disturbed repository (Case IIA) is well within these guidelines and natural background radiation exposure levels. If, however, the groundwater flow parameters are considerably poorer than expected (Cases IIB and IIC), the doses predicted are at or above the radiation guidelines. The highest total dose would occur in Case IIC in which transport parameters are degraded and no engineering modifications are postulated to minimize the impacts. The Case IIC peak is 129 mrem/50yr at about 1500 yr after the intruding borehole is plugged and abandoned. Precompaction of the waste is estimated to reduce the predicted doses by 44 percent (Case IIB vs. Case IIC). Similarly, degraded conditions combined with expected mitigation modifications (Case IID) result in predicted committed doses which are well within applicable guidelines.

Integrated release: The calculations of radionuclide concentrations and resultant exposure at an assumed stock well due to human intrusion cannot be used, as such, to establish total integrated release at a controlled boundary over a 10,000 year period. Integrated release calculations require two-dimensional models of hydrologic transport in the Culebra aquifer. However, for comparison purposes, the releases over 10,000 years are estimated by making simplified analyses and broad assumptions. The hypothesized stock well is the only location at which the concentration histories are calculated. Therefore, concentrations are calculated along a hypothetical boundary located at the hypothetical stock well 3 mi south of the center of the site. Assuming a maximum plume width at the stock well boundary over the entire 10,000 years yields an upper bound to the integrated release calculation. Assuming a minimum plume width for the entire 10,000 years at the stock well boundary yields a smaller value for the integrated release. Both these calculations are conservative in that this simplified analysis assumes that all contaminants travel along the fastest flow path without any lateral dispersion. With these assumptions, an estimate is provided for the intgrated release at the stock well boundary for each individual radionuclide over the 10,000 year period; this can be used to estimate the fraction this constitutes of the limit values obtained from Appendix A of 40 CFR Part 191.

The radionuclides used to calculate the WIPP release limits are among those identified in the EPA standard, Table 1, Appendix A; namely transuranic alpha-emitting isotopes with half-lives greater than 20 years. The best estimate of the total inventory of these isotopes is 5.1×10^6 curies. Consequently, the release limits are 5.1 times the total values listed in Table 1. (The additional radioactivity that comprises the total 9.8×10^6 curie inventory for the WIPP are fission products or transuranics of less than 20 year half-life or non-alpha emitters.)

The total release for the upper bound intrusion analysis ranges from approximately five times the total release limit in the standard for degraded transport parameters (Case IIC) down to 9×10^{-7} times the limit for the expected conditions (Case IIA). The lower value of release ranges from 0.3 times the limit for Case IIC to 7×10^{-7} times the limit for Case IIA.

These scenario calculations do not permit a full comparison with the geologic disposal standards' probabilistic release limits, even in a deterministic sense. The calculations in the SEIS were performed at the location nearest the repository for which it is reasonable to expect that Culebra groundwater could enter the human food chain. This location, however, is beyond the proposed WIPP land withdrawal boundary, and, therefore, beyond the limit of the "accessible environment" defined in 40 CFR Part 191. Nevertheless, the results suggest that appropriate Performance Assessment methods and likely values of parameters would show that the WIPP would comply with the standard. They also indicate the efficiency of potential engineering modifications, should the results of Performance Assessment prove unacceptable, assuming the present waste form.

NO ACTION ALTERNATIVE

Under the No Action Alternative, TRU waste would not be shipped and emplaced in the WIPP. TRU waste would continue to be generated and stored at the DOE defense program facilities. Impacts at the WIPP from implementing a No Action alternative would be dependent upon the final status of the facility.

If the No Action Alternative was selected, there would be no risk to the public from transportation of TRU waste to the WIPP. Shipment of TRU waste to interim storage facilities would continue. Similarly, since TRU wastes would not be emplaced at the WIPP, there would be no radiological consequences to workers. Routine exposures would continue to occur at the interim storage facilities.

The impacts at the Idaho National Engineering Laboratory of not opening the WIPP were addressed in the FEIS. TRU waste presently in retrievable storage at the Idaho National Engineering Laboratory would remain in storage for an indeterminate period or could be transferred to another storage facility. Waste would either continue to be shipped to Idaho National Engineering Laboratory from other DOE facilities or be placed at other interim storage sites. Continued storage of waste at the Idaho National Engineering Laboratory would result in limited radiation releases in the short term from either routine operation or accidents. The FEIS concluded that no environmental reasons were found why TRU waste could not continue to be stored at the Idaho National Engineering Laboratory as it presently is for several decades.

Over the long term, the No Action Alternative could result in potential exposures from various disruptive events and/or human intrusion, because of the lack of a permanent disposal facility. The FEIS concluded that volcanic activity holds the greatest potential risk for long-term accidental release of radionuclides.

In 1988, DOE prepared an environmental assessment for the management of retrievable and newly-generated TRU waste at the Savannah River Plant. This assessment indicated that the greatest dose associated with continued TRU waste storage would result from a drum fire. Under these conditions, the maximum dose to offsite individuals was calculated to be 4400 mrems. The offsite population was estimated to receive 20,000 person-rems.

A Final Envirionmental Impact Statement was prepared in 1987 which addressed the impacts at the Hanford Reservation of not opening the WIPP. The estimated total-body radiation dose to the workforce at the Hanford Reservation from continued storage was 20 person-rem. The potential total body doses resulting from various human intrusion scenarios involving drilling or excavation into retrievably-stored TRU waste could range from 0.0004 to 4 rem/year.

MITIGATION MEASURES

The SEIS describes mitigation measures that have been implemented at the WIPP site, proposed measures, and some conceptual measures that could potentially be applied if information gathered during the Test Phase reveals a need for such mitigation to ensure adequate long-term performance of the repository.

Since the FEIS was issued, geologic and hydrologic concerns have been raised relative to long-term repository performance. Geologic concerns are principally related to salt fracturing, and hydrologic concerns focus on brine inflow and potential pathways to water-bearing zones. Excavation of underground rooms at the WIPP have resulted in fracturing of the surrounding rock creating a "disturbed rock zone." The disturbed rock zone is a volume of rock whose mechanical properties (e.g., the elastic modulus) and hydraulic properties (e.g., permeability and fluid inflow) have been changed by mining. Disturbed rock zones may provide pathways through which fluid can bypass the tunnel and shaft seals.

Fluid movement around seals may be mitigated by excavating around the disturbed rock zone and by immediately emplacing the seal before the rock has an opportunity to fracture to a large extent. Similarly, fluid movement around seals within an underlying anhydrite layer (Marker Bed 139) may be mitigated by excavating the anhydrite layer, emplacing seals, and grouting around it.

Studies since 1980 have raised the concern of potential brine inflow; mitigation may involve the emplacement of selected backfill materials, and sealing possible routes through which brine could migrate to the shafts and upward to the Culebra water-bearing zone. Backfill materials under consideration include crushed salt or a 70:30 mixture of crushed salt and bentonite. Other additives that remove gases from the system by absorption may also be mixed with the backfill.

The FEIS recognized the need to plug remaining holes and shafts when the WIPP is being decommissioned. Current plans are still to seal all holes and shafts, in order to eliminate the pathways where waste material might migrate to the overlying Culebra water-bearing zone or even the ground surface. A number of tunnel seals are now planned to isolate the different parts of the underground facility from the shafts. Tunnels would be sealed following waste emplacement with preconsolidated crushed salt. Salt-bentonite layers would be laid where the shaft intersects anhydrite beds. All other intervals in the Salado Formation would be filled with salt. In the Rustler Formation, a complex set of concrete and salt-bentonite sections is being considered to seal that formation's numerous water-bearing beds.

Waste treatment influences gas generation, repository void volume, and radionuclide and heavy metal solubility. Possible mitigation technologies include immobilization, incineration, and compaction. Immobilization technologies include the use of asphalts, cements and grouts, clay, pelletization, polymers, salt cakes, and glass (i.e., vitrification). Incineration of radioactive waste reduces the volume of the very low-level, combustible trash resulting from the operation of radioactive material handling systems. Operationally, incineration burns off the combustible constituents of the waste leaving an inorganic ash which is much easier to immobilize. Compaction or super-compaction is a method of volume reduction that can be applied to compressible waste.

A final determination on specific requirements for potential engineering modifications and waste treatments, if necessary, would be made upon completion of the proposed Test Phase.

1.0 PURPOSE AND NEED FOR ACTION

1.1 BACKGROUND

The U.S. Department of Energy (DOE) is nearing completion of major construction activities at the Waste Isolation Pilot Plant (WIPP) in southeastern New Mexico, 26 miles southeast of Carlsbad. The surface facilities are essentially complete, and most of the underground experimentation rooms and waste rooms for initial waste emplacement have been excavated. Additional waste rooms will be mined in advance of waste emplacement. The WIPP underground facility, which is 2150 feet below the land surface in a 3000-foot-thick bedded salt and anhydrite formation, is being constructed as a repository for transuranic (TRU) waste from DOE defense-related facilities. The TRU waste to be disposed of at the WIPP results primarily from defense-related plutonium reprocessing and fabrication as well as defense-related research activities at DOE facilities. The volumes and characteristics of TRU wastes are discussed in Subsection 2.4 and Appendix B of this Supplemental Environmental Impact Statement (SEIS).

The WIPP was authorized by the Department of Energy National Security and Military Applications of Nuclear Energy Act of 1980, (Public Law 96-164). The Act provides as follows:

> Notwithstanding any other provision of law, the Waste Isolation Pilot Plant is authorized as a defense activity of the Department of Energy. . .for the express purpose of providing a research and development facility to demonstrate the safe disposal of radioactive wastes resulting from the defense activities and programs of the United States exempted from regulation by the Nuclear Regulatory Commission.

The Act also requires the DOE to consult and cooperate with the State of New Mexico with respect to public health and safety concerns. This consultation-and-cooperation process is governed by the written agreement discussed in Subsection 10.3.1 of this SEIS.

The DOE proposes to initiate use of the WIPP in late 1989 to conduct certain experimental and operational tests during a Test Phase of approximately five years. These tests will not begin until the completion of 1) certification that the containers to be used for shipping the TRU wastes to the WIPP meet regulatory requirements, 2) the receipt of the needed legislative or administrative authority to withdraw public lands for WIPP use, 3) completion of pre-operational readiness analyses, and 4) satisfaction of all applicable environmental requirements.

The storage of TRU waste in aboveground facilities that were designed only for interim storage might pose safety, environmental, and health problems if continued for the long term. The Governors of the States of Colorado and Idaho have expressed concern over the continued interim storage of TRU waste at the Rocky Flats Plant and the Idaho National Engineering Laboratory and the unavailability of the WIPP as a permanent TRU-waste repository. In addition, the delay of the WIPP project holds the potential to adversely affect the nation's production of nuclear weapons.

1.2 NEPA COMPLIANCE

1.2.1 1980 WIPP FEIS

The 1980 WIPP Final Environmental Impact Statement (FEIS) and the associated public review and comment provided environmental input for the DOE's initial decision to proceed with the WIPP (DOE, 1980). The significance of impacts associated with the various alternatives was assessed. For the selected alternative, a two-phased approach to development was proposed: 1) a site and preliminary design validation (SPDV) program, as discussed in Subsection 8.2.1 of the FEIS, and 2) full construction, as discussed in FEIS Subsection 8.2.2. The durations of key WIPP activities are shown in Figure 1.1.

The 1980 FEIS presented an analysis of the environmental impacts of a number of alternatives for demonstrating the safe disposal of TRU waste. The alternatives considered included:

- Alternative 1. No action, including permitting the TRU waste to continue to be stored at the present storage site at the Idaho National Engineering Laboratory and not constructing or operating the WIPP.
- Alternative 2. Constructing the WIPP at the Los Medanos site in southeastern New Mexico.
- Alternative 3. Disposing of stored TRU waste in the first available repository for high-level radioactive waste.
- Alternative 4. Delaying a decision on the site for a WIPP until at least 1984 to allow for the investigation of alternative sites.

Alternative methods and geologic media for TRU-waste disposal were also considered but rejected in the FEIS. The alternative methods included burial in deep ocean sediments, emplacement in deep drillholes, transmutation, and ejection into space. The alternative geologic media included igneous, volcanic, and argillaceous rocks.

The DOE's Record of Decision (ROD), published January 28, 1981 (48 FR 9162), announced the DOE's selection of Alternative 2. The analysis in the supporting FEIS and ROD concluded that any adverse environmental impacts of Alternative 2 would be generally minor and that the Los Medanos site in southeastern New Mexico would be acceptable for the long-term disposal of TRU waste with "minimal risk of any release of radioactivity to the environment" (DOE, 1981).

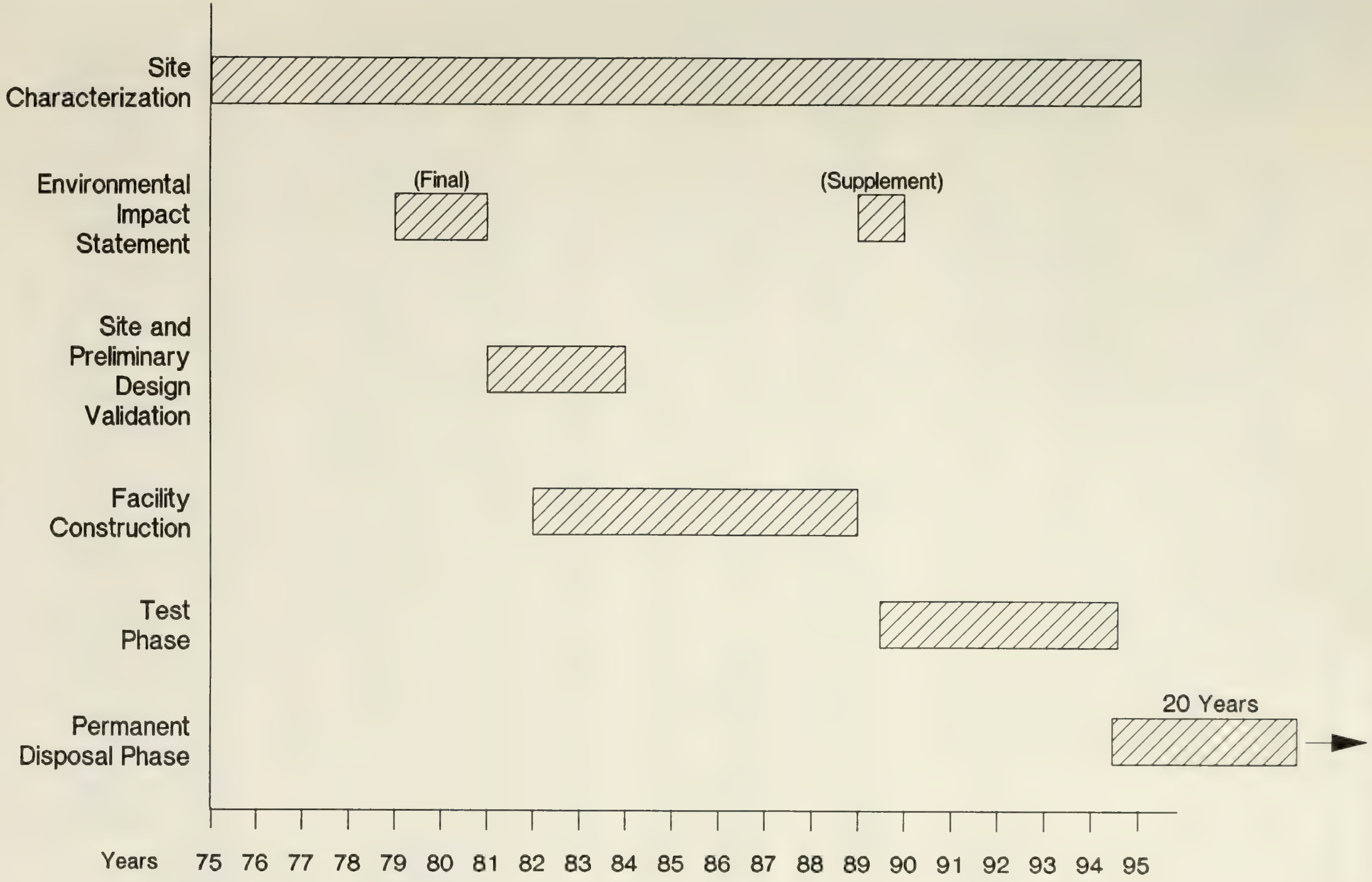

Figure 1 . 1 Key WIPP Activities

1.2.2 NEPA Documentation Since the FEIS

The Record of Decision stated the following:

> If significant new environmental data results from the SPDV program or other WIPP project activities, the FEIS will be supplemented as appropriate to reflect such data, and this decision to proceed with phased construction and operation of the WIPP facility will be reexamined in the light of that supplemental National Environmental Policy Act (NEPA) review.

The Council on Environmental Quality (CEQ) regulations for implementing NEPA procedures (40 CFR Parts 1500-1508) require supplements either to draft or to final environmental impact statements if 1) the agency makes substantial changes in the proposed action relevant to environmental concerns or 2) there are significant new circumstances or information relevant to environmental concerns that bear on the proposed action or its impacts. Agencies may also prepare supplemental environmental impact statements on their own initiative when "the purposes of the Act (NEPA) will be furthered in doing so" [40 CFR Part 1502.9(c)].

In April 1982, the DOE prepared an environmental analysis to determine the significance of proposed cost-reduction measures regarding the construction of the WIPP and concluded that the potential environmental impact would not be significant (DOE, 1982).

The DOE performed a similar environmental analysis of the results of the Site and Preliminary Design Validation Program in 1983 to determine whether the conclusions stated in the ROD remained valid. The DOE determined that "the new information either falls within the bounds of the impacts discussed in the FEIS or represents insignificant change" (DOE, 1983).

1.3 PURPOSE AND NEED FOR SUPPLEMENT

Since the publication of the FEIS in October 1980 and the subsequent Record of Decision to proceed with the phased construction and operation of the WIPP, new geologic and hydrologic information has led to changes in the understanding of the hydrogeologic characteristics of the area as they relate to the long-term performance of the WIPP. In addition, several changes have occurred in the proposed action and in the information and assumptions used to calculate the impacts reported in the FEIS. These include changes in the composition of the waste inventory, the transportation of waste to the WIPP, the Test Phase, and the management of TRU mixed waste, which has hazardous chemical constituents.

This SEIS evaluates the environmental consequences of the proposed action as modified since 1980 in light of new information and assumptions. Modifications to the proposed action since 1980 that are examined in this SEIS are as follows:

- Addition of TRU wastes from other DOE defense program facilities. The analysis in the 1980 FEIS considered only TRU wastes from the Idaho National Engineering Laboratory and Rocky Flats Plant. Since then, the DOE has completed additional NEPA documentation (DOE 1988a, 1987), and has proposed that stored TRU wastes from the Hanford Reservation and the Savannah River Plant be disposed of at the WIPP. Eventually, TRU wastes from six other facilities may also be proposed for disposal at the WIPP. (The impacts of retrieving and processing wastes at these sites will be the subject of separate NEPA evaluations as appropriate.)

- Changes in the TRU radionuclide inventory, including the identification of high-curie and high-neutron waste and the elimination of experiments with high-level waste (SEIS Subsection 3.1.1.1).

- Consideration of the hazardous chemical constituents of TRU mixed waste (SEIS Subsection 3.1.1.2).

- Changes in waste transportation including packaging, routes, and modes (SEIS Subsection 3.1.1.3).

- Addition of the Test Phase (SEIS Subsection 3.1.1.4).

The new data and information and the resulting interpretations principally address the geologic and hydrologic systems at the WIPP site. They include:

- Determination of a lower permeability in the Salado Formation, the geologic formation in which the WIPP underground facilities are located (SEIS Subsection 4.3.2).

- Determination of a potentially higher moisture content in the Salado Formation and consequent brine inflow (SEIS Subsection 4.3.2).

- Discovery of a higher transmissivity zone in the Rustler Formation in the southeastern portion of the WIPP site (SEIS Subsection 4.3.3).

  New data leading to a conclusion that "salt creep" (convergence) in the repository occurs faster than previously believed (SEIS Subsection 4.3.2).

In addition, the effects of removing and processing the TRU waste stored at the Idaho National Engineering Laboratory have been revised to reflect new information and analyses since the 1980 FEIS (SEIS Subsection 5.2.1).

1.4 PROPOSED ACTION

The proposed action is to proceed with a phased approach to determine whether the WIPP should become a permanent repository for defense-program TRU wastes. The next phase of the WIPP project would involve conducting certain experiments and operational demonstrations. During this Test Phase (approximately 5 years), experiments would be conducted to reduce the uncertainties associated with the prediction of several natural processes (e.g., gas generation, brine inflow, and salt deformation) that bear on repository performance. In addition, operations would be conducted to show the ability of the TRU-waste-management system to safely and efficiently certify, package, transport, and emplace waste in the WIPP.

This SEIS analyzes the impacts of a test phase conducted with a volume of TRU waste that represents up to 10 percent of the total design waste volume of the WIPP to bound impacts. Although 10 percent has been selected to ensure that the impacts of the proposed Test Phase are bounded, the amount of TRU wastes needed for the Test Phase may be smaller. The results of the experiments would be used to assess the ability of the WIPP to meet regulatory requirements for the long-term protection of the environment from the disposal of TRU wastes. At the conclusion of the Test Phase, the DOE would decide whether, on the basis of a performance assessment, the WIPP would comply with the standards issued by the U.S. Environmental Protection Agency (EPA) for the disposal of TRU wastes. If there is a determination of compliance, the WIPP would move into the disposal phase for demonstrating the safe disposal of defense-generated TRU wastes. If there is a determination of noncompliance, a number of options would be considered (e.g., waste treatment) and the required NEPA documentation would be prepared.

Two alternatives to the proposed action are considered in this SEIS: 1) no action and 2) the alternative conduct only those tests that can be performed without the emplacement of wastes underground until there is a determination of WIPP compliance with regulatory requirements for the long-term protection of the environment from the disposal of TRU wastes.

1.5 CONTENT OF THE SEIS

The timing of this SEIS is such that certain regulatory-compliance issues for the WIPP project are unresolved. These include the radiation-protection standards promulgated by the EPA for the disposal of TRU wastes in 40 CFR Part 191 (Subpart B of which was vacated and remanded to the EPA by a U.S. Court of Appeals), procedural issues for the certification by the U.S. Nuclear Regulatory Commission (NRC) of the Transuranic Package Transporter (TRUPACT-II), and compliance with the requirements of the Resource Conservation and Recovery Act (RCRA). Although these standards and requirements provide a framework for analyses in this SEIS, it is not the purpose of this SEIS to resolve these issues or to demonstrate compliance with regulatory requirements.

The remainder of this SEIS is divided into nine major sections. These sections are summarized as follows:

- Section 2, Background: An Overview of the WIPP. This section presents a description of the WIPP as it currently exists.
- Section 3, Description of the Proposed Action and Alternatives. The proposed action is to proceed with the development and operation of the WIPP as described in the FEIS and as modified by changes described in this SEIS. There are two alternatives to the proposed action, the no action alternative and an alternative action involving tests performed without the

emplacement of wastes underground in an attempt to determine if WIPP can comply with regulatory requirements.

- Section 4, Description of the Existing Environment. This section summarizes and updates the description of the existing environment provided in the FEIS. New understanding of the hydrogeologic system at the WIPP site is highlighted in SEIS Subsections 4.2 and 4.3.
- Section 5, Environmental Consequences. This section presents analyses of postulated radioactivity and hazardous-chemical releases, exposures, and consequences resulting from routine transportation and operations as well as those resulting from transportation or operational accidents[a]. Subsection 5.4 addresses decommissioning and long-term repository performance.
- Section 6, Mitigation Measures. This section summarizes the mitigation measures discussed in the FEIS and discusses the mitigation measures that have been implemented in support of WIPP construction activities or may be implemented to minimize potential adverse environmental impacts of the WIPP.
- Section 7, Unavoidable Adverse Impacts. This section briefly reiterates the findings included in the FEIS and presents new findings.
- Section 8, Short-Term Uses and Long-Term Productivity. This section briefly reiterates the findings included in the FEIS and presents new findings.
- Section 9, Irreversible and Irretrievable Commitments of Resources. This section briefly reiterates the findings included in the FEIS and presents new findings.
- Section 10, Environmental Regulatory Requirements. This section discusses additional regulatory requirements since the FEIS, including the applicable RCRA requirements and the EPA standards for the management and disposal of TRU wastes.

The FEIS has been reprinted and is being distributed to the public and reviewing agencies as background to the SEIS. Additionally, copies of the SEIS and the FEIS have been placed in the designated DOE reading rooms and public libraries. A listing of these locations is provided in Appendix K. Copies of key documents referenced in

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[a] Note, the draft SEIS assesses the environmental impacts that may result from the WIPP Disposal Phase operations in Subsection 5.2.3. This assessment is based on the numerical values and projections made in the December 1988 draft of the Final Safety Analysis Report (FSAR) for the WIPP (DOE, 1988b) which has been reviewed by the preparing contractor and DOE. The draft FSAR is currently undergoing further review by the DOE headquarters, New Mexico's Environmental Evaluation Group, and others. If changes to the draft FSAR result from this review process, the final SEIS will be updated to reflect these changes as appropriate.

the SEIS are available in the designated DOE reading rooms. The SEIS employs cross-referencing to the FEIS and referencing of other relevant material as provided by 40 CFR 1502.21. This has been done to reduce the document's length, enhance readability, and avoid unnecessary redundancy.

Table 1.1 cross-references the environmental topics addressed in the FEIS and the SEIS and lists the sections in the FEIS that have not changed significantly. To the extent possible, the SEIS has remained consistent with the FEIS by employing English units of measurement for commonly used units and metric units for more-technical subject areas as appropriate.

1.6 OVERVIEW OF CONSULTATIONS

Prior to the preparation of this SEIS, the DOE briefed representatives of 21 State governments, five Congressional delegations, key Congressional committees and subcommittees, various Indian nations, and environmental groups regarding the SEIS and related issues and sought input from these groups on key issues that should be addressed in the SEIS. These consultations are described in greater detail in Appendix H.

The Bureau of Land Management (BLM) is a cooperating agency in support of the SEIS in accordance with 40 CFR 1501.6. Public comments obtained during public hearings on this draft SEIS, as well as all other public (including written) comments submitted to the DOE on the SEIS, will be provided to the BLM in its role as a cooperating agency on the draft SEIS.

TABLE 1.1 Cross-references between the FEIS and the SEIS by section number

	FEIS Section		SEIS Section
1	SUMMARY	SUMMARY	
1.1	Background		Purpose and Need
1.2	Alternatives		Background
1.3	The Los Medanos Site		Description of Alternatives
1.4	Environmental Evaluation of Alternatives		Existing Environment
1.5	Conclusions		
2	BACKGROUND	1	PURPOSE AND NEED FOR ACTION
2.1	Brief Introduction to this Document	1.1	Background
		1.2	NEPA Compliance
		1.3	Purpose and Need for Supplement
		1.5	Contents of the SEIS
		1.6	Overview of Consultations
2.2	Waste Management Programs Leading to the Consideration of the Los Medanos Site		(Further discussion in this SEIS is unnecessary)
2.3	Defense Transuranic Waste	2.3	Waste Types and Forms
		3.1	Proposed Action

TABLE 1.1 Continued

	FEIS Section		SEIS Section
3	DEVELOPMENT OF ALTERNATIVES	3	DESCRIPTION OF THE PROPOSED ACTION AND ALTERNATIVES
3.1	The Alternative of No Action	3.2.1	No Action Alternative
3.2	Alternative Disposal Methods		(Further discussion in this SEIS is unnecessary)
3.3	Alternatives for Geologic Disposal		(Further discussion in this SEIS is unnecessary)
3.4	Alternative Areas in Bedded Salt		(Further discussion in this SEIS is unnecessary)
3.5	Alternative Sites in Alternative Media		(Further discussion in this SEIS is unnecessary)
3.6	Formulation of Alternatives	3	Description of the Proposed Action and Alternatives
		3.2	Alternatives
		3.3	Alternatives not Considered in Detail
4	ENVIRONMENTAL IMPACTS OF ALTERNATIVES	5	ENVIRONMENTAL CONSEQUENCES
4.1	Alternative 1: No Action	5.5	No Action Alternative
4.2	Alternative 2: The Authorized WIPP Facility	5.1	Environmental Impacts of Implementation of FEIS Selected Alternative
		5.2	Environmental Impacts of SEIS Proposed Alternative
		5.4	Decommissioning and Long-Term Performance
		App. I	Methods and Data Used in Long-Term Consequence Analysis
4.3	Alternative 3: The Preferred Alternative: Combine the Authorized WIPP Activities with the First Available High-Level-Waste Repository		(Further discussion in this SEIS is unnecessary)
4.4	Alternative 4: A Defense-Waste Facility Built After the Consideration of Sites in Addition to Los Medanos		(Further discussion in this SEIS is unnecessary)
4.5	Tabular Comparison of Alternatives		Summary

TABLE 1.1 Continued

FEIS Section		SEIS Section	
5	WASTE FORMS	2.3	Waste Types and Forms
		App. B	Waste Characteristics
5.1	Waste-Acceptance Criteria	2.3.1	Waste Acceptance Criteria
		App. A	Waste Isolation Pilot Plant Waste Acceptance Criteria
5.2	Acceptance Criteria Assumed for Analyses Reported in this Document	2.3.1	Waste Acceptance Criteria
		App. A	Waste Isolation Pilot Plant Waste Acceptance Criteria
5.3	Processing of Transuranic Waste	2.3.2	Processing of TRU Waste
6	TRANSPORTATION OF WASTE TO THE WIPP	3.1.1.3	Transportation of TRU Wastes to the WIPP
6.1	Regulations	10.2.1	Resource Conservation and Recovery Act of 1976
		10.2.6	Nuclear Regulatory Commission (NRC) TRUPACT-II Certification
		App. D	Transportation and Transportation-related Risk Assessment
6.2	Organizations Responsible for Regulating Transportation	App. D	Transportation and Transportation-related Risk Assessment
6.3	Packages and Packaging Systems	3.1.1.3	Transportation of TRU Wastes to the WIPP
6.4	Routes	3.1.1.3	Transportation of TRU Wastes to the WIPP
6.5	Volumes of Waste and Number of Shipments	3.1.1.3	Transportation of TRU Wastes to the WIPP
		5.2.2	Transportation
6.6	Cost of Transporting Contact-Handled TRU Waste to the WIPP		(Further discussion in this SEIS is not necessary)
6.7	Radiological Impacts of Waste Transport Under Normal Conditions	5.2.2, 5.3.7, 5.5.7	Transportation
		App. D	Transportation and Transportation-related Risk Assessment
6.8	Radiological Impacts of Waste Transport Under Accident Conditions	5.2.2, 5.3.7, 5.5.7	Transportation
		App. D	Transportation and Transportation-related Risk Assessment

TABLE 1.1 Continued

FEIS Section			SEIS Section	
	6.9	Nonradiological Impacts of Waste Transport Under Accident Conditions	5.2.2, 5.3.7, 5.5.7	Transportation
			App. D	Transportation and Transportation-related Risk Assessment
	6.10	Intentional Destructive Acts		(Further discussion in this SEIS is not necessary)
	6.11	Emergency Procedures	2.8	Transportation Emergency Planning
			App. C	Transportation Emergency Planning
	6.12	Financial Responsibility for Accidents	App. D	Transportation and Transportation-related Risk Assessment
7		THE LOS MEDANOS SITE AND ENVIRONMENTAL INTERFACES	4	DESCRIPTION OF THE EXISTING ENVIRONMENT
	7.1	Biophysical Environment	4.1	Existing Environment at the WIPP Site
	7.2	Sociocultural Environment	4.1.2	Socioeconomic Environment
	7.3	Geology	4.2	Geology
			App. E	Permeability Measurements and Brine Inflow Rates
	7.4	Hydrology	4.3	Hydrology and Water Quality
			App. E	Permeability Measurements and Brine Inflow Rates
8		THE WIPP AND ITS OPERATION	2	Background: An Overview of the WIPP
	8.1	Description and Use of the Site		Further discussion in this SEIS is not necessary
	8.2	General Description of the WIPP	2	Background: An Overview of WIPP
	8.3	Surface Facilities and Operations	2.2.1	Surface Facilities

TABLE 1.1 Continued

	FEIS Section		SEIS Section
8.4	Underground Facilities and Operation	2.2.2	Underground Facilities
8.5	Systems for Handling Radioactive Waste Generated at the Site		(Not readdressed; FEIS discussion is still relevant)
8.6	Sources of the Potential Release of Radioactive Materials Not readdressed (FEIS discussion is still relevant)		(Not readdressed; FEIS discussion is still relevant)
8.7	Nonradioactive Waste		(Not readdressed; FEIS discussion is still relevant)
8.8	Auxiliary Systems		(Not readdressed; FEIS discussion is still relevant)
8.9	Research and Development Program	3.1.1.4	Implementation of a Test Phase
8.10	Plans for Retrieval	2.5	Waste Retrieval
8.11	Plans for Decommissioning	2.6	Plans for Decommissioning
8.12	Emergency Planning, Security, and Safeguards	2.7	Site Emergency Planning and Security
9	ANALYSIS OF ENVIRONMENTAL IMPACTS OF THE WIPP	5	ENVIRONMENTAL CONSEQUENCES
9.1	Actions Affecting the Environment	5.1	Environmental Impact of Implementation of the FEIS Selected Alternative
9.2	Effects During Site Preparation and Construction		(Further discussion in this SEIS unnecessary)
9.3	Effects of Plant Operation	5.2	Environmental Impact of the SEIS Proposed Alternative
9.4	Economic and Social Effects of Plant Construction and Operation	5.1.2	Socioeconomics
9.5	Environmental Effects of Accidents During Operation	5.2.3	Risk Assessment and Analysis of Radiological and Environmental Consequences of Operations and Possible Retrieval at the WIPP
		5.2.4	Risk Assessment and Analysis of Hazardous Chemical Environmental Consequences of Operations and Possible Retrieval at the WIPP

TABLE 1.1 Continued

	FEIS Section		SEIS Section
		5.3.8	Radiological Assessment-Operation
			Summary
		App. F	Radiological Release and Dose Modeling for Permanent Disposal Operations
		App. G	Toxicity Profiles, Risk Assessment Methodology, and Models For Chemical Hazards
9.6	Mitigation of Impacts	6	MITIGATION MEASURES
9.7	Long-Term Effects	5.4	Decommissioning and Long-Term Performance
		App. I	Methods and Data Used in Long-Term Consequence Analysis
9.8	Effects of Removing the TRU Waste Stored at INEL	5.2.1	Waste Retrieval from the INEL
10	UNAVOIDABLE ADVERSE IMPACTS	7	UNAVOIDABLE ADVERSE IMPACTS
10.1	Construction	7.1	Construction
10.2	Operation	7.2	Operation
10.3	Long-Term Impacts	7.3	Long-Term Impacts
10.4	Comparison of Alternatives		Summary
11	IRREVERSIBLE AND IRRETRIEVABLE COMMITMENTS OF RESOURCES	9	IRREVERSIBLE AND IRRETRIEVABLE COMMITMENTS OF RESOURCES
11.1	Land Use	9.1	Land Use
11.2	Denial of Mineral Resources	9.2	Denial of Mineral Resources
11.3	Resources for WIPP Resources	9.3	Commitment of Resources for WIPP Construction
11.4	Resources for WIPP Operation	9.4	Commitment of Resources for WIPP Operation

TABLE 1.1 Continued

FEIS Section		SEIS Section	
11.5	Resources Used at the Idaho National Engineering Laboratory		(Further discussion in this SEIS is unnecessary)
11.6	Comparison of Alternatives		Summary
12	RELATION TO LAND-USE PLANS, POLICIES, AND CONTROLS		(Not readdressed; FEIS discussion is still relevant)
12.1	Existing Land-Use Plans, Policies, and Controls		(Not readdressed; FEIS discussion is still relevant)
12.2	Compatibility of the WIPP Project with Existing Land-Use Plans		(Not readdressed; FEIS discussion is still relevant)
12.3	Comparison of Alternatives		Not included
13	RELATIONSHIP BETWEEN SHORT-TERM USES AND LONG-TERM PRODUCTIVITY	8	SHORT-TERM USES AND LONG-TERM PRODUCTIVITY
14	ENVIRONMENTAL PERMITS, APPROVALS, CONSULTATIONS, AND COMPLIANCES	10	ENVIRONMENTAL REGULATORY REQUIREMENTS
14.1	Introduction	10	ENVIRONMENTAL REGULATORY REQUIREMENTS
14.2	Federal and State Permits and Approvals	10.2	Additional Permits, Approvals, and Consultations
14.3	Consultations	10.2.5	Consultations with the State of New Mexico
14.4	Public Participation	App. H	Public Information and Intergovernmental Affairs
15	PUBLIC AND AGENCY COMMENTS		(Not applicable to draft SEIS)
App. A	Alternative Geologic Environments		(Not readdressed; further discussion in this SEIS is unnecessary)
App. B	The National Waste Terminal Storage Program and Alternative Geologic Regions		(Not readdressed; further discussion in this SEIS is unnecessary)
App. C	President Carter's Message to Congress on the Management of Radioactive Waste and the Findings and Recommendations of the Interagency Review Group on Nuclear Waste Management		(Not readdressed; further discussion in this SEIS is unnecessary)
App. D	Selection Criteria for the WIPP Site		(Not readdressed; further discussion in this SEIS is unnecessary)

TABLE 1.1 Concluded

FEIS Section		SEIS Section	
App. E	Descriptions of Waste Types	App. B	Waste Characteristics
App. F	Incineration and Immobilization Processes	6.4	Mitigation by Waste Treatment
App. G	Methods Used To Calculate Radiation Doses from Radionuclide Releases During Operation	App. F	Radiological Release and Dose Modeling for Permanent Disposal Operations
		App. G	Toxicity Profiles, Risk Assessment Methodology And Models For Chemical Hazards
App. H	Description of the Los Medanos Site		(Not readdressed; FEIS discussion is still relevant)
App. I	Correspondence on Archaeology, Historic Sites, Prime Farm Land, and Endangered Species		(Not readdressed; FEIS discussion is still relevant)
App. J	Effluent and Environmental Measurements and Monitoring Programs	2.10	Environmental Monitoring Programs
App. K	Methods Used in Long-Term Safety Analyses	App. I	Methods and Data used in Long-Term Consequence Analyses
App. L	An Outline of the Input-Output Model and Impact Projections Methodology		(Not readdressed)
App. M	Socioeconomic Effects of Plant Construction and Operation: Supporting Data		(Not readdressed)
App. N	Effects of Leaving the TRU Waste at INEL		(Not readdressed; FEIS discussion is still relevant)
App. O	Interpretation of Radiation Doses Predicted in this Document	App. F	Radiological Release and Dose Modeling for Permanent Disposal Operations
		App. I	Methods and Data Used in Long-Term Consequence Analyses
App. P	Comments from Federal and State Agencies on the Draft Environmental Impact Statement for the Waste Isolation Pilot Plant		(Not applicable)
App. Q	Report of the Hearings Panel on the Draft Environmental Impact Statement on the Waste Isolation Pilot Plant		(Not applicable)

REFERENCES FOR SECTION 1

DOE (U.S. Department of Energy), 1988a. Environmental Assessment, Management Activities for Retrieved and Newly-generated Transuranic Waste, Savannah River Plant, DOE/EA-0315.

DOE (U.S. Department of Energy), 1988b, December. Final Safety Analysis Report, Waste Isolation Pilot Plant, Carlsbad, New Mexico, draft, DOE/WIPP 88-xxx, Albuquerque, New Mexico.

DOE (U.S. Department of Energy), 1987. Final Environmental Impact Statement, Disposal of Hanford Defense High-Level, Transuranic and Tank Wastes, Hanford Site, Richland, Washington, DOE/EIS-0113, Volumes 1 through 5.

DOE (U.S. Department of Energy), 1983. "National Environmental Policy Act (NEPA) Review of the Waste Isolation Pilot Plant (WIPP) Site and Preliminary Design Validation (SPDV) Program," letter dated June 28, 1983, William A. Vaughan (Assistant Secretary, Environmental Protection, Safety, and Emergency Preparedness) to Herman E. Roser (Assistant Secretary for Defense Programs).

DOE (U.S. Department of Energy), 1982. "Review of the Environmental Analysis for the Cost Reduction Proposal for the WIPP Project," letter dated July 8, 1982, William A. Vaughan (Assistant Secretary, Environmental Protection, Safety, and Emergency Preparedness) to Herman E. Roser (Assistant Secretary for Defense Programs).

DOE (U.S. Department of Energy), 1981. "Waste Isolation Pilot Plant (WIPP); Record of Decision," Federal Register, Vol. 46, No. 18, p. 9162, January 28, 1981 (46 FR 9162).

DOE (U.S. Department of Energy), 1980. Final Environmental Impact Statement, Waste Isolation Pilot Plant, DOE/EIS-0026, Volumes 1 and 2, Washington, D.C.

2.0 BACKGROUND: AN OVERVIEW OF THE WIPP

This section provides an overview of the WIPP as currently constructed, the waste types and waste forms proposed for emplacement in the WIPP, the WIPP Waste Acceptance Criteria (WAC), and the control zones that define the WIPP site. The construction of the WIPP, planning for decommissioning, and emergency preparedness and response planning have proceeded since the FEIS. Also, several environmental monitoring programs have been undertaken since the FEIS. These programs are described in Subsection 2.9, and their results are summarized in Section 4.

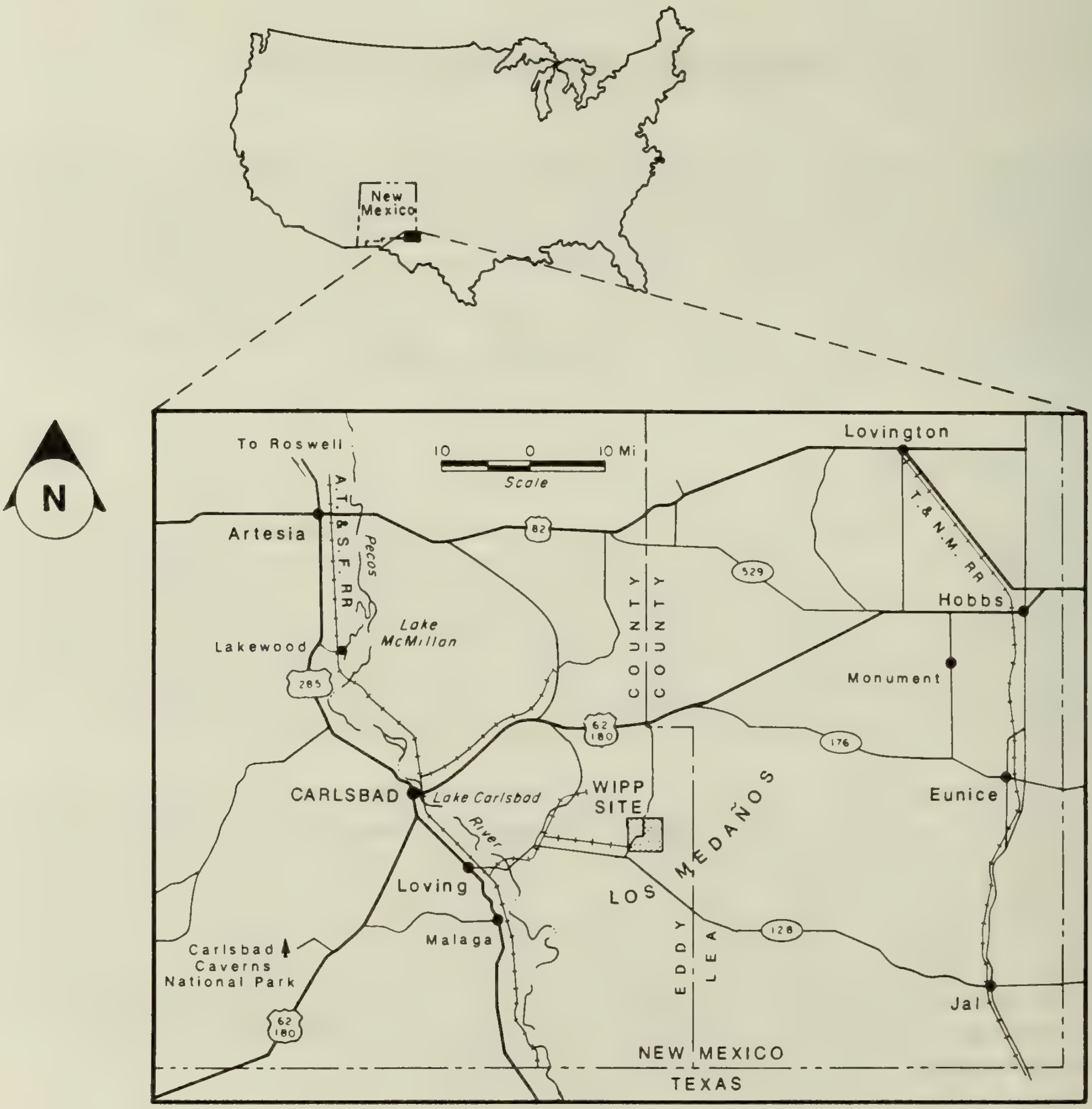
2.1 LOCATION

The WIPP site is located in Eddy County in southeastern New Mexico (Figure 2.1) (FEIS Subsection 8.1). The site is approximately 26 miles southeast of Carlsbad in an area known as Los Medanos (which translates as "the dunes"), a relatively flat, sparsely inhabited plateau with little surface water and limited land uses. The land is now owned by the Federal Government and administered by the Bureau of Land Management (BLM). The land is primarily used for grazing. Other land uses in the area around the WIPP include potash mining and oil and gas exploration and development.

In 1980, the WIPP site consisted of Zones I through IV (Figure 8-2 in Subsection 8.1 of the FEIS). Control Zones I through III consisted of 14 sections of BLM land and two sections of State land in Township 22 South, Range 31 East. Portions of an additional 20 sections were included in WIPP Zone IV. All 36 sections were to be under full control of the DOE. Zone I included all surface facilities, Zone II defined the maximum extent of underground activities, Zone III provided a 1-mile buffer area around Zone II, and Zone IV represented the area where the DOE would control access to resources. Grazing was to be allowed in Zones II through IV, but mining and drilling activities, as well as habitation, were to be controlled by the DOE.

The DOE has since eliminated the requirement to control the land identified as Zone IV in the FEIS, and the public land order creating the WIPP site made Control Zone III unnecessary. Figure 2.2 illustrates the present location of the WIPP site boundaries. Reduction of the WIPP control area allowed resources beneath this area to become more accessible relative to the analysis presented in the FEIS. As a result, 71 percent of the denied sylvite resources, 65 percent of the denied langbeinite resources, and 57 percent of the crude oil, natural gas, and distillate resources became available.

The lands within the WIPP site boundaries are currently withdrawn from settlement, sale, location, or entry under the general land laws, including mining laws, by Public Land Order 6403, dated June 29, 1983. Leasing under the Taylor Grazing Act has continued under the present land withdrawal, to the extent it is not incompatible with the WIPP activities.



REF: DOE, 1980.

FIGURE 2.1

LOCATION OF THE WIPP SITE

The WIPP site is currently divided into two zones. Control Zone I is within the Secured Area shown in Figure 2.2. This zone encloses approximately 35 acres in Sections 20 and 21 of Township 22 South, Range 31 East, and has not changed since the FEIS. The Secured Area is fenced with barbed wire and includes approximately 250 acres with restricted access.

Zone II indicates the maximum extent of underground development and has not changed since the FEIS. The WIPP site boundary extends at least 1 mile beyond any underground development and is defined on the surface by the 16-section land withdrawal area. This boundary provides a functional barrier of intact salt between the underground region defined by Control Zone II and the accessible environment.

The WIPP site also includes the DOE Exclusive Use Area, which currently consists of 640 acres under the exclusive control of the DOE. The boundary of this area is between the boundaries of the Secured Area and Control Zone II (Figure 2.2). The DOE has proposed to expand this exclusive use area to include 1454 acres.

2.2 FACILITIES

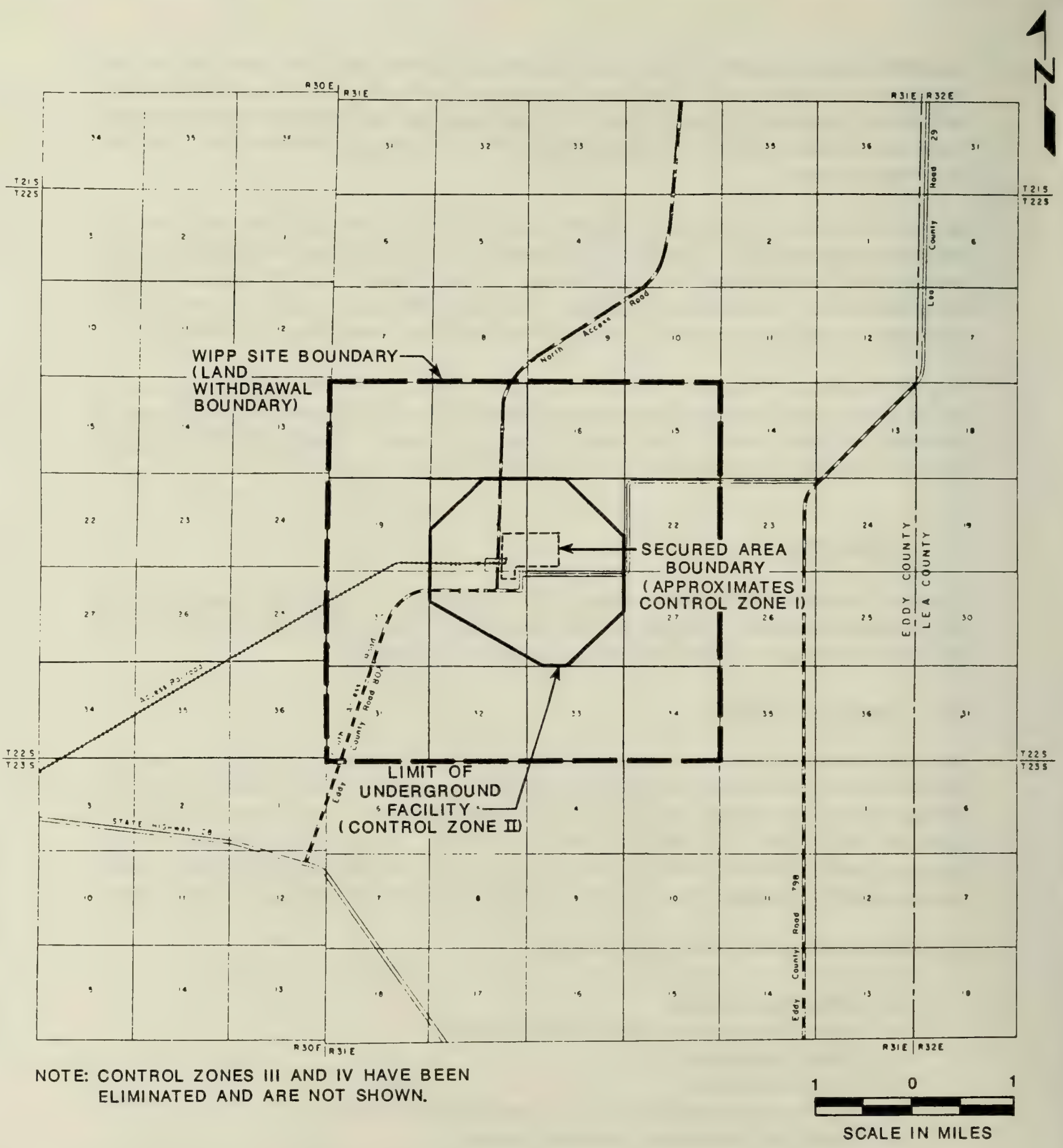
The WIPP includes surface and underground facilities that would support waste-handling and emplacement tasks. These facilities, discussed in Subsections 8.2, 8.3, and 8.4 of the FEIS, have been constructed and are briefly described here.

2.2.1 Surface Facilities

The principal surface structure at the WIPP is the waste handling building (Figure 2.3), which includes areas for the receipt, inventory, inspection, and transfer of contact-handled (CH) and remote-handled (RH) TRU waste through separate air locks to a common waste shaft (FEIS Subsections 8.2 and 8.3). It also houses offices, change rooms, a health physics laboratory, and equipment for ventilation and filtration. Safety equipment and measures for controlling radiation exposure are included in the building.

Other surface facilities constructed include:

- Shaft filter building
- Various warehouse buildings and trailers
- Water pumphouse
- Support Building
- Construction management and maintenance complex
- Safety and emergency services building
- TRUPACT-II maintenance building (attached to the waste handling building)
- Guard and security building.



NOTE: CONTROL ZONES III AND IV HAVE BEEN ELIMINATED AND ARE NOT SHOWN.

FIGURE 2.2

CURRENT BOUNDARIES OF THE WIPP SITE

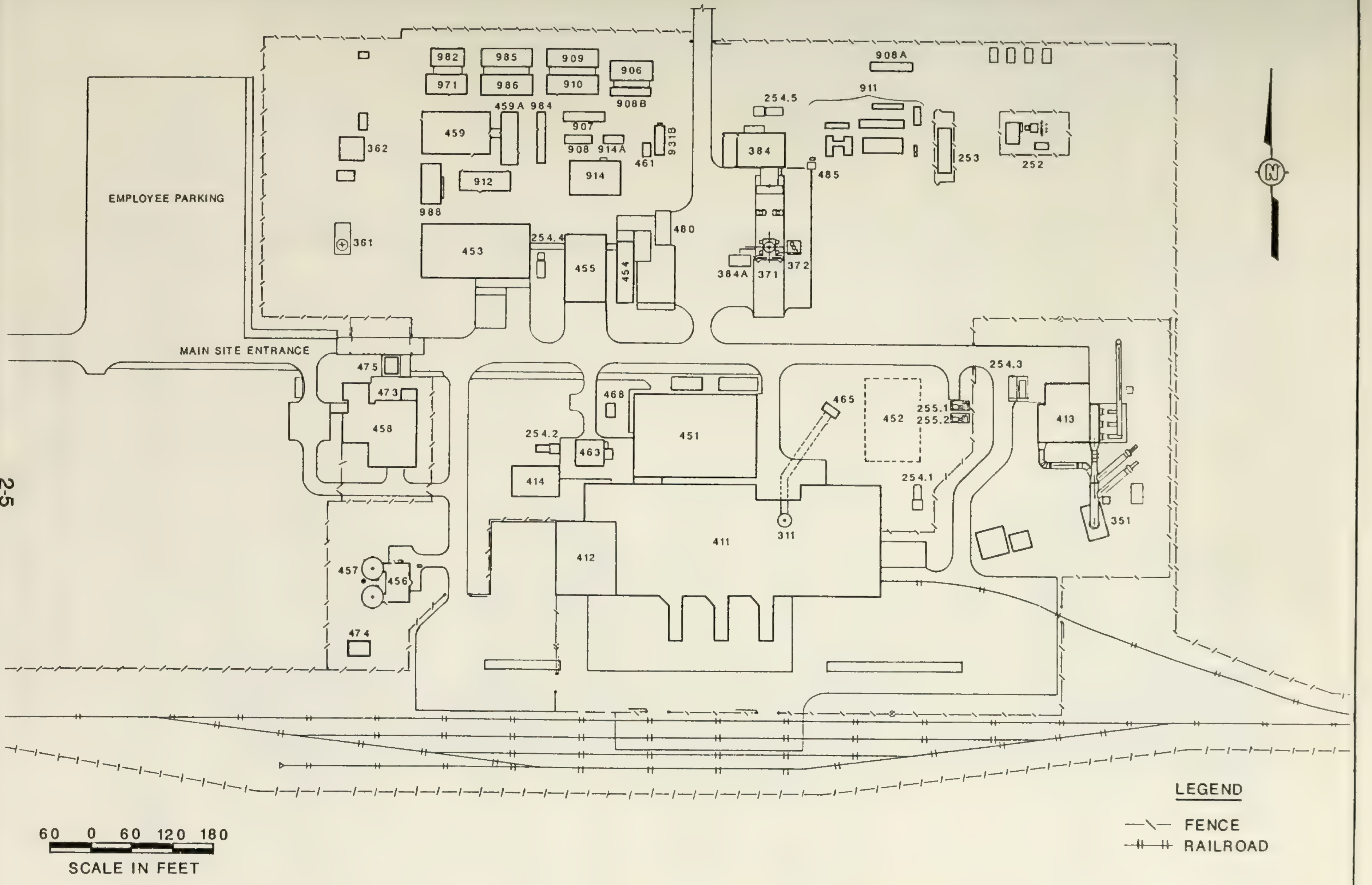


FIGURE 2.3

SURFACE FACILITIES AT THE WIPP

FACILITIES AND STRUCTURES

SOUTHWESTERN PUBLIC SERVICE UTILITY SUBSTATION	252
13.8 KV SWITCHGEAR 25P-SW15.1	253
AREA SUBSTATION NO. 1 25P-SW15.1	254.1
AREA SUBSTATION NO. 2 25P-SW15.2	254.2
AREA SUBSTATION NO. 3 25P-SW15.3	254.3
AREA SUBSTATION NO. 4 25P-SW15.4	254.4
AREA SUBSTATION NO. 5 25P-SW15.5Q	254.5
EMERGENCY GENERATOR #1 25-PE 503	255.1
EMERGENCY GENERATOR #2 25-PE 504	255.2
WASTE SHAFT	311
EXHAUST SHAFT	351
AIR INTAKE SHAFT	361
AIR INTAKE SHAFT HOIST/WINCH HOUSE	362
CONSTRUCTION AND SALT HANDLING SHAFT	371
CONSTRUCTION AND SALT HANDLING HEADFRAME	372
CONSTRUCTION AND SALT HANDLING HOISTHOUSE	384
LAMPHOUSE	384A
WASTE HANDLING BUILDING	411
TRUPACT MAINTENANCE BUILDING	412
EXHAUST SHAFT FILTER BUILDING	413
WATER CHILLER FACILITY	414
SUPPORT BUILDING	451
SAFETY & EMERGENCY SERVICE FACILITIES	452
WAREHOUSE/SHOPS BUILDING	453
VEHICLE SERVICE BUILDING	454
AUXILIARY WAREHOUSE BUILDING	455
WATER PUMP HOUSE	456
WATER TANKS (2)	457
GUARD AND SECURITY BUILDING	458
CORE STORAGE BUILDING	459
SANDIA ANNEX	459A
FIRE HUT	461
COMPRESSOR BUILDING	463
AUXILIARY AIR INTAKE	465
TELEPHONE HUT	468
METEOROLOGICAL BUILDING (NORTHEAST OF SITE)	472
ARMORY BUILDING	473
HAZARDOUS WASTE STORAGE BUILDING	474
GATEHOUSE	475
VEHICLE FUEL STATION	480
SULLAIR COMPRESSOR BUILDING	485
MISCELLANEOUS & QUALITY ASSURANCE	906
ENVIRONMENTAL EVALUATION GROUP TRAILER	907
PROJECT PLANNING & CONTROL TRAILER	908
SANDIA NATIONAL LABORATORIES CABLE TRAILER	908A
INTERNATIONAL TECHNOLOGIES, INC., CABLE TRAILER	908B
SAFETY TRAILER	909
ENVIRONMENTAL, HEALTH AND SAFETY	910
SANDIA TRAILER COMPLEX	911
SANDIA CALIBRATION LAB #1	911A
SANDIA M101	911B
SANDIA ANNEX	911C
SANDIA MOBILE TRANSPORT	911D
SANDIA CALIBRATION LAB #2	911E
SANDIA B49 AND B49 ANNEX	911F
TRAINING TRAILER	912
CONSTRUCTION MANAGEMENT AND MAINTENANCE COMPLEX	914
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FIGURE 2.3 (CONCLUDED)
SURFACE FACILITIES AT THE WIPP

The safety and emergency services building provides housing for the safety and environmental protection personnel and an indoor garage for site emergency vehicles. Any required maintenance on the TRUPACT-IIs would be conducted at the TRUPACT maintenance building, which is attached to the waste handling building.

2.2.2 Underground Facilities

The constructed underground facilities include four shafts, the waste-disposal area, the experimental area, an equipment and maintenance facility, and connecting tunnels (FEIS Subsections 8.2 and 8.4). The four shafts (Figure 2.4) from the surface to the underground area are:

- Air intake shaft
- Salt-handling shaft
- Waste-handling shaft
- Exhaust shaft

The underground facility, as described in Subsection 8.2.2.2 of the FEIS, was mined in the Salado Formation, 2,150 ft beneath the surface. The waste disposal area was mined in the same design as described in the FEIS, but was reconfigured slightly because of pressurized brine-reservoirs south of the described location in the Salado Formation. The "room and pillar" arrangement includes two separate mined areas:

- CH and RH TRU waste disposal area (100 acres designed to hold 6.2 million ft^3 of CH TRU and 250,000 ft^3 of RH TRU waste). To date, about 15 acres have been mined.

- Experimental area (12 acres) used for repository safety and mine performance studies.

Not all waste-disposal rooms have been mined at present, because of the natural phenomenon of salt creep, which causes eventual room closure. Additional waste-disposal rooms would be mined in advance of permanent waste emplacement.

2.3 WASTE TYPES AND FORMS

Defense-generated TRU wastes result primarily from plutonium reprocessing and fabrication as well as research and development activities at various DOE defense program facilities. TRU wastes are materials contaminated with alpha-emitting radionuclides having atomic numbers greater than 92, half-lives greater than 20 years,

reclassified as low-level wastes, which would not be sent to the WIPP. TRU wastes exist in a variety of physical forms, ranging from unprocessed laboratory trash (e.g., tools, paper, glassware, gloves) to solidified wastewater treatment sludges (Appendix B).

2	2-7	2.3, line 6	(SEIS Subsection 3.1.1.2) should read (SEIS Subsection 3.1.1.1).

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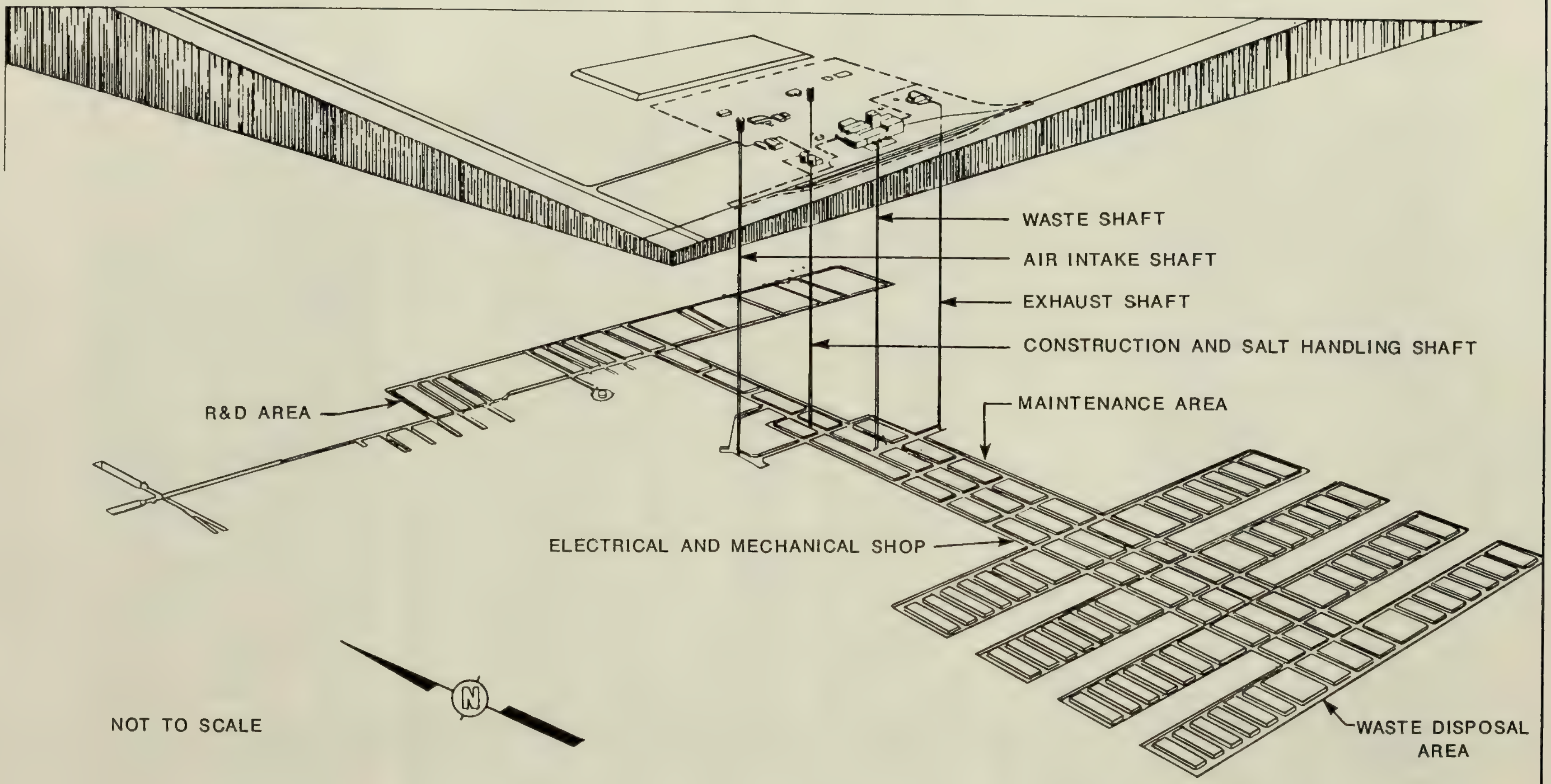

FIGURE 2.4
SCHEMATIC OF THE WIPP REPOSITORY

TRU waste is classified according to the radiation dose rate at the package surface. The greatest percentage of defense TRU waste by volume (97 percent) is CH TRU waste, which primarily emits alpha radiation. These radionuclides, while potentially dangerous if inhaled or ingested, do not represent an external radiation hazard.
CH TRU waste has radiation dose rates at the package surface below 200 millirem per hour (mrem/hr) and can be safely contact-handled (i.e., personnel may directly handle these waste packages without excessive radiation exposure). CH TRU waste is packaged in sealed steel drums and boxes. Approximately 3 percent by volume of defense TRU waste is RH waste, which contains isotopes that emit beta and gamma radiation as well as alpha radiation. This waste has a package surface radiation dose rate exceeding 200 mrem/hr and must be remotely handled. (SEIS Appendix A describes waste-package surface dose rate restrictions.) RH TRU waste requires heavy shielding for safe handling and storage, so it is handled and transported in lead-shielded casks. SEIS Subsection 3.1.1 provides a comparison of CH and RH TRU waste volumes considered in the FEIS and in this SEIS; SEIS Subsection 3.1.1 provides a description of the changes in the waste types (e.g., high-curie and high-neutron) that may be disposed of at the WIPP.

Potentially hazardous chemical constituents are often commingled with TRU waste from defense-related operations resulting in a classification of waste referred to as "mixed waste." The hazardous chemical components of defense TRU mixed waste were not addressed in the FEIS. TRU wastes containing hazardous chemical constituents have similar physical and radiological characteristics to those TRU wastes that do not contain these constituents. A major chemical constituent in TRU waste is lead, which is present predominantly in the form of glove box parts, and lead-lined gloves and aprons. Other metals (e.g., cadmium, chromium, uranium, and barium) also occur in some of the wastes (e.g., sludges), but in much smaller quantities. Organic solvents (e.g., methylene chloride, toluene) are present in some waste types. These solvents exist primarily in residual quantities from the cleaning of equipment, plastics, and glassware. SEIS Subsection 3.1.1.2 presents the characteristics of the hazardous chemical constituents of defense TRU mixed wastes.

2.3.1 Waste Acceptance Criteria (WAC)

The DOE has established Waste Acceptance Criteria (WAC) for wastes coming to the WIPP (DOE, 1989). These criteria establish conditions governing the physical, radiological, and chemical composition of the waste to be emplaced in the WIPP, as well as specifications for waste packaging. The DOE established the WAC in consideration of the Department of Transportation (DOT) and the Nuclear Regulatory Commission (NRC) regulations. The DOT regulates the safe transport of radioactive and hazardous materials. The NRC will be asked to issue a certificate of compliance for the TRUPACT-II shipping container (SEIS Subsection 10.2.6 and Appendix D) (DOE, 1988a).

The WAC were established with the assumption that the radiological hazards of TRU waste are much greater than hazards from associated nonradiological chemical constituents. Therefore, the WAC focus on the radiological properties of the waste, while the chemical criteria of the WAC are primarily oriented toward the prevention of immediate hazards such as fire and explosion. The WAC do not require detailed characterization of chemical constituents of the waste because waste sampling and analysis would result in increased radiological exposure of personnel. However, the labeling and data package criteria of the WAC provide for the identification of hazardous chemical characteristics of TRU mixed waste in compliance with the RCRA.

A detailed discussion of the WAC and the basis upon which these criteria were established are contained in a recent report (DOE, 1989). A summary of the current WAC is given in SEIS Appendix A. The changes to the WAC since 1980 (FEIS Subsection 5.1) are summarized below:

- Gas Generation. Eliminated the volume and density limits by requiring filtered pressure relief vents on waste packages and provided for data relevant to calculation of gas generation. Added prohibition of gases that could dramatically reduce the effectiveness of the packaging during transportation.

- Immobilization. Replaced requirement for immobilization of all powders with requirement for immobilization if more than one percent by weight of the powder is composed of particulates less than 10 microns (μm) in diameter or if more than 15 percent by weight is less than 200 μm in diameter. The requirement for no free liquids was revised to allow minor liquid residues remaining in drained containers. Limits were provided on dispersibility of such liquids in case of a breach.

- Toxics and Corrosives. Revised to include "radioactive mixed wastes" and added a requirement to report the quantities of these constituents for accumulation records.

- Sludges. Requirements were deleted; sludges are now covered under immobilization requirements.

- Waste Container Design Life. Twenty years from the date of certification.

- Waste Package Weight. Reduced from 25,000 lb to 21,000 lb.

- Criticality. RH TRU waste increased from less than 5 grams per cubic foot of fissionable radionuclide content (g/ft^3) to no greater than 53.7 g/ft^3 or 600 g total if partitioned in 55-gal drums at 200 g each.

- Thermal Power. RH TRU waste reduced from 500 watts (W) to 300 W to limit maximum underground heat load.

- Specific Activity. Added requirement that the concentration of TRU radionuclides must be greater than 100 nCi/g to segregate low-level waste from TRU waste.

- Activity Concentration. Added requirement that the concentration of activity is limited to 23 curies per liter (Ci/l) averaged over the volume.

In addition, a concept of "plutonium-239 equivalent activity" (PE-Ci) was introduced in the WAC changes (SEIS Appendix F). The PE-Ci concept was intended to eliminate the need for site-specific radiological analyses and instead depends on knowledge of the specific radionuclide composition of a TRU waste stream. A unique radionuclide composition is associated with virtually every TRU waste generator and storage facility. By "normalizing" radionuclides to a common radiotoxic hazard index, radiological analyses can be conducted for the WIPP that are independent of these variations. Plutonium-239, as a common component of essentially all defense TRU wastes, was selected as the radionuclide to which the radiotoxic hazard of other TRU radionuclides could be indexed.

The FEIS did not use the 1,000 PE-Ci limit established subsequently in the WAC for calculating occupational and public doses during routine and accident conditions. The FEIS used representative waste from the Rocky Flats Plant for radiological analyses. Subsequent to the FEIS, radiological performance analyses for normal operations and operational accident scenarios using the 1,000 PE-Ci limit were performed to support amendment 9 of the WIPP draft Final Safety Analysis Report (FSAR) (DOE, 1988a).[a] These analyses demonstrated that the somewhat higher projected doses do not change the radiological consequences significantly and that these doses remain well within prescribed regulatory limits and/or guidelines.

To demonstrate compliance with the WAC, the DOE requires that generators handling defense TRU waste develop and implement a program that establishes procedures for waste certification and quality assurance. Each site-specific plan identifies and describes the administrative controls and procedures required to characterize TRU waste, segregate and process waste forms, and package waste in accordance with the WAC. Stored TRU waste will undergo nondestructive, nonintrusive analyses, such as container integrity examinations, weighing, radiographic examinations, fissile inventory examination, and radiographic surveys of containers prior to certification. A waste certification officer at each generator facility inspects each container of waste and certifies in writing that the waste meets the specifications of the WAC. An independent DOE Certification Committee conducts either an annual or biennial audit of each facility's certification program, depending on the quantities of TRU wastes generated at the facility, and approves the certification program for wastes to be shipped to the WIPP.

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[a] The draft SEIS assesses the environmental impacts that may result from the WIPP Permanent Disposal Phase in Subsection 5.2.3. This assessment is based on the numerical values and projections made in the December 1988 draft of the Final Safety Analysis Report (FSAR) for the WIPP (DOE,1988a), which has been reviewed by the preparing contractor and DOE. The draft FSAR is currently undergoing further review by the DOE headquarters, New Mexico's Environmental Evaluation Group, and others. If changes to the draft FSAR result from this review process, the final SEIS will be updated to reflect these changes as appropriate.

2.3.2 Processing of TRU Waste

Since the FEIS was issued, the development of the WAC (SEIS Subsection 2.3.1) has made certain waste processing and packaging practices unacceptable. The DOT and NRC transportation requirements have imposed additional restrictions on waste form. As a result, some generator facility practices have changed and activities at facilities for retrievably-stored waste have been modified.

Gas generation considerations for transportation have resulted in the introduction of vented waste packages at some generator facilities. The vents in such packages incorporate HEPA (high-efficiency particulate air) grade carbon composite filters. Prior to shipment, packages will have these vents.

The WAC requirement for immobilization of ashes and powders has impacted the handling of these materials. Floor sweepings, machine cuttings, and similar materials are now being immobilized in cement or other media. Proposed waste processing systems at generator facilities have been designed to reflect the requirements of the WAC for such ash and powder substances. Representative processing systems are described in SEIS Subsection 6.4.1.

The WAC limits free liquid in waste packages to small residual amounts. This criterion is being met by a combination of generator facility actions. In some cases, improved process control and the addition of absorbents have ensured that packaged sludges meet the free liquid criterion. There is also a trend for generators to modify their liquid and sludge processing practices to provide a monolithic solid waste form. These practices are described in SEIS Subsection 6.4.1.

Approximately 60 percent of the stored waste is estimated to be classified as mixed waste with radioactive and hazardous chemical components. Current generator facility practices minimize the number of mixed-waste packages by a combination of improved waste segregation and reduction of the use of hazardous chemical materials. The WAC's elimination of explosives and compressed gases is also being addressed by improved controls during waste segregation and packaging.

Some facilities use reactive, potentially pyrophoric metals in their operations. Wastes containing these metals are now being processed to reduce reactivity either by chemical reaction or by immobilization.

2.4 WASTE RECEIPT AND EMPLACEMENT

Procedures for receiving and handling waste aboveground at the WIPP's waste handling building are described in Subsection 8.3.1 of the FEIS and remain unchanged. Wastes would enter the building through air locks that control the movement of air. Three such air locks provide for entry into the CH TRU waste side of the building. The air locks are designed to help maintain the interior of the building at a pressure lower than atmospheric. The doors at each end of the air lock are interlocked to prevent both doors from being opened simultaneously. The air locks help ensure that airflow is into the building, thereby precluding the inadvertent release of potential radioactive contamination from the building.

The ventilation system is designated as a dynamic confinement barrier in the building's multibarrier confinement system. In the waste handling areas the ventilation system maintains a static pressure differential (negative pressure) between the primary confinement barriers (drums, boxes) and the environment. Air locks between different design zones of potential contamination are designed to separate areas in which critical pressure differentials are maintained to ensure airflow from areas of lower to higher contamination potential. The HEPA filtration system acts as a secondary confinement barrier. This system connects with the dynamic ventilation system and provides the last barrier to prevent any contaminated airborne particulates from leaving the plant. The design is such that individual filters can be replaced without any air bypassing the HEPA system (DOE, 1988a).

2.4.1 Waste Receipt

During the Test Phase under the proposed action, RH and CH TRU waste would be received and emplaced at the WIPP in such a way as to maintain retrievability. CH TRU waste would be received in two forms of Type A packagings, 55-gal drums or standard waste boxes (SWBs) (boxes 37 inches high by 72 inches in diameter), which are in turn contained within Type B shipping packagings (TRUPACT-II). Each TRUPACT-II would contain fourteen 55-gal drums or two SWBs (SEIS Subsection 3.1.1.3). The packages would be checked for surface contamination, and if uncontaminated, would be unloaded in the receiving and inspection area.

Contaminated packages would be moved to the overpack and repair room, where they would be examined and overpacked or repaired if necessary. When inspection (sampling of TRUPACT-II atmosphere and swipe testing) shows that the waste packages are uncontaminated and structurally intact and if the accompanying documentation shows that they meet the WIPP WAC (DOE, 1989) and regulatory requirements (40 CFR Part 264, Subpart E--Manifest System, Recordkeeping, and Reporting), they would be moved to the CH TRU waste inventory and preparation area. At that location, packages would be stacked on pallets for uniform handling and would be transferred underground through the waste shaft. The TRUPACT-IIs, emptied of the waste packages, would be decontaminated, if necessary, for reuse and loaded onto transport vehicles leaving the plant.

RH TRU waste would be received in DOT- and NRC-approved (Type B) shielded shipping casks. Each cask, containing one canister of waste, would be inspected and unloaded in the cask unloading and receiving area of the waste handling building. It would then be moved to the cask preparation and decontamination area. At this location, any contamination would be removed and special handling equipment would be attached to the cask. These operations would be performed with RH equipment to prevent personnel exposure to radiation.

The RH casks would be transferred to the cask unloading room, where the canisters would be removed and placed in a shielded "hot cell." After identification and inspection, during which any contaminated canister would be overpacked, the canister would be placed in the transfer cell. Within the transfer cell, the canister would be loaded into a specially designed facility cask and lowered underground via the waste shaft. The shipping cask would be decontaminated, if necessary, and returned to the shipper for reuse.

2.4.2 Waste Emplacement

CH TRU waste would be transferred on pallets to the underground waste receiving station in a hoist cage designed to handle a payload of 45 tons. At this station, the waste pallets would be unloaded and transported by forklift to the waste-disposal areas. A decontamination and radiation safety check station would be located near the waste shaft on the waste-disposal level.

During the Test Phase, backfilling with crushed salt and/or other additives would only be undertaken to the extent necessary to satisfy the goals of the tests and in a manner that allows for waste retrieval (i.e., not allowing salt creep to crush the waste packages). During the Disposal Phase, each room (33 ft wide, 13 ft high, 300 ft long) would be backfilled with crushed salt and/or other additives (e.g., bentonite, gas- absorbing materials) as the containers are emplaced.

The RH TRU waste facility cask would be lowered in the hoist cage to the underground waste receiving station and transported by forklift to a waste disposal area. The RH TRU waste canisters would be horizontally emplaced in holes in the walls of the disposal rooms or selected drifts.

2.5 WASTE RETRIEVAL

During the Test Phase, the waste emplaced in the WIPP must be readily and safely retrievable. Based upon the results of the Test Phase, the DOE would decide whether to retrieve the waste. Retrieval of waste is essentially the reverse of waste placement, as the waste-container integrity is not expected to change during the Test Phase; waste containers would occupy only a limited portion of each room, so salt creep would not damage containers during this phase.

The retrieval process for CH TRU waste can be summarized as follows:

- Monitor for radiation and hazardous chemicals to determine personnel safety requirements for waste removal
- Stack drums or boxes on pallets by forklift for return to the waste handling shaft
- Return waste to the waste handling building for transportation away from the site
- Decontaminate the floor or other surfaces of the WIPP, if necessary, by mechanical removal of contaminated salt

- Place any contaminated salt in containers and handle as CH TRU waste.

A decision as to whether to retrieve the waste that would be emplaced during the Test Phase would be made after a determination of compliance with Subpart B of 40 CFR Part 191, the EPA disposal standards for TRU waste. In the Disposal Phase, the WIPP would be designed and operated to comply with the assurance requirement of 191.14(f) of 40 CFR 191 that "... removal of most of the wastes will not be precluded for a reasonable period of time after disposal."

If during the Test Phase there were a determination of noncompliance with Subpart B of 40 CFR Part 191, a number of options would be considered and any required NEPA documentation prepared. These include:

- Additional waste treatment at the WIPP or at another DOE facility
- Additional engineering barriers and/or design modifications of the WIPP
- Interim storage of the waste at the WIPP or another facility while options are evaluated.

If it were determined during the Test Phase that some treatment of the waste (e.g., incineration, compaction, other) would be required to meet applicable regulations, an evaluation process would commence to evaluate whether treatment should occur at the WIPP or at another location. This evaluation would consider such factors as the cost of new facility construction at the WIPP, the potential effects of TRU waste transport to other facilities, and the attendant environmental impacts. Any required NEPA documentation would be prepared.

If engineering additions are proposed for the WIPP, the waste would either be brought to the surface or moved to other subsurface storage areas within the WIPP and temporarily stored in an environmentally safe manner. Such storage would continue only until such time as engineering and design modifications can be completed and permanent disposal of the waste could be accomplished. If only the addition of a modified backfill is required, it could possibly be installed with the waste in place or by moving the waste from the Test Phase locations to new locations, and emplacing it with the appropriate backfill at new locations.

Finally, if wastes are required to be shipped from the WIPP to another facility for interim storage, they might not be sent back to the generator or storage facility of their origin because of the costs of double handling and the transportation impacts.

2.6 PLANS FOR DECOMMISSIONING

When the disposal operations cease or if a decision is made not to proceed into the Disposal Phase at the WIPP, the site would be decommissioned in a way that would allow for the safe, permanent disposition of surface and underground facilities consistent with the then applicable regulations. Plans for decommissioning remain the same as in the FEIS (Subsection 8.11) and include the following options:

- Mothballing. The plant would be placed in protective storage for a few decades, which would allow for later repository operation or experiments. The facilities would be left intact and any radioactive areas would be isolated from the public by barriers. Complete radiation monitoring, environmental surveillance, and security procedures would be established to protect the environment and public health and safety.

- Entombment. Usable equipment would be decontaminated and removed. Equipment that may not be decontaminated would remain underground. Entombment would require filling the mine with salt and plugging the shafts and boreholes. The surface facilities would then be available for future use.

- Dismantling. The plant would be entombed as above. Surface facilities would be decontaminated, demolished, or dismantled, and debris removed. The site landscape would be returned to as near its original condition as possible.

- Converting. The plant would be put to another use when WIPP operations are complete. This would take advantage of roads, rail spurs, and utilities currently at the site.

The option that the DOE is currently considering is dismantling. Administrative controls consistent with 40 CFR Part 191 would be imposed to minimize human intrusion, such as deep drilling, mining, or any activity that might allow water to penetrate into the disposal area. It is expected that the shafts would be permanently marked with durable warning monuments. Documents concerning the WIPP would be maintained in public document repositories.

The WIPP is subject to 40 CFR Part 265, RCRA Interim Status Standards. Subpart G of Part 265 covers closure (the period when wastes are no longer accepted and the site is decontaminated and prepared for decommissioning) and the postclosure period (the period following complete closure when the area is monitored and maintained to ensure integrity of the disposal system). Consistent with these regulations, closure and post-closure plans would be prepared and maintained at the WIPP site. The closure plan would describe partial closure of each unit (room), final closure of the facility, and waste retrievability features. If waste is retrieved after the Test Phase, the closure plan would be amended in accordance with 40 CFR 264.112 (WEC, 1988).

2.7 SITE EMERGENCY PLANNING AND SECURITY

The FEIS (Subsection 8.12) describes precautions, emergency actions, and procedures to be taken in response to radiation-related and other emergencies at the WIPP. Procedures and actions include:

- Advance training and coordination with local law-enforcement, fire, and medical personnel

- A central monitor/control system to coordinate and record all emergency alarms, and serve as a control center during emergencies

- Location and maintenance of firefighting vehicles aboveground and belowground

- A medical facility capable of treating contaminated, injured persons before their transfer to a hospital

- Written procedures specifying response to the unplanned release of radioactivity, fire, cave-ins, explosions, radiation, and other emergencies

- An emergency-response force composed of personnel (firefighting, medical, security, mine rescue, radiation control) who would take immediate action to assess, control, contain, and recover from the emergency

- Special immediate action training and formal qualification for the emergency response force

- Set up and staffing of the Emergency Operations Center (EOC) with senior management personnel. The EOC is activated to provide centralized response to emergencies.

- Quarterly emergency response drills utilizing specially developed contingency scenarios to test the capabilities of emergency response personnel.

These actions and procedures have been accomplished and are currently in place at the WIPP site and in the communities of Hobbs and Carlsbad, New Mexico. Additionally, drills have been conducted to test capabilities, primarily in the areas of security, underground fire, surface fire, medical emergencies, underground evacuation, mine rescue, and radioactive spills and contamination. The EOC has been utilized during most of these drills.

At the conclusion of each drill, action assignments are established to improve response capability. Corrective action, the person responsible, and the date the action is due are noted in the "plan of the day" log at the WIPP. Action items are reviewed in daily planning meetings and removed from the log only when the improvement has been made.

Memoranda of Understanding have been executed with medical, fire, and law-enforcement personnel in Carlsbad and Hobbs, New Mexico. In 1986 the DOE and Eddy County, New Mexico, signed a mutual aid agreement in which the Otis Volunteer Fire Department agreed to respond to the WIPP site fires. In turn, the WIPP committed its forces to respond to fire, medical, and rescue situations within a 60-square-mi area of Eddy County. As a result, the WIPP Emergency Action Team has responded to traffic accidents and suppressed one major fire. The policy is to respond to anyone in need of help where life or health is involved, as long as it does not jeopardize the safety or security of the WIPP site.

The site security plan for the WIPP complies with DOE Order 5632.2A (DOE, 1988b) regarding guards, fencing, building construction, and access control. It also meets RCRA security requirements, including "a 24-hour surveillance system which continuously controls entry onto the active portion of the facility, a fence which completely surrounds the active portion of the facility, a means to control entry, at all times, through the gates or other entrances to the active portion of the facility, and signs with the legend 'Danger-Unauthorized Personnel Keep Out'. . .written in English and in any other language predominant in the area surrounding the facility," in this case, Spanish (40 CFR 265.14).

Additional security provisions for the site have been implemented, including security clearances for selected site employees, visit and assignment authorization for foreign nationals, visitor documentation, information protection, and key and lock controls (DOE, 1988a). Since the FEIS was completed, upgrades have been proposed to extend the Zone I fence, expand the fenced security area from 250 to 1,454 acres, prohibit grazing inside the security area, and arm the security staff.

2.8 TRANSPORTATION EMERGENCY PLANNING

The transportation emergency-preparedness program described in Subsection 6.11 of the FEIS has been implemented (SEIS Appendix C). Achievements of this ongoing program to date include:

- Interfaces with local, State, Federal government agencies, and Indian tribal governments have been established
- The States Training and Education Program for first responders is on schedule
- The public awareness tour has been completed in five States and has received much positive media coverage
- The transport tracking system hardware and software have been tested and proven; this system has been made available to State and Federal government agencies and Indian tribal governments. The system would provide accurate tracking of shipments to the WIPP.

This subsection describes the progress that has been made in these programs since publication of the FEIS and includes discussion of the overall emergency-preparedness plan, implementation of the plan, State emergency plans, and response training.

As discussed in Subsection 2.7 above, an overall emergency-preparedness plan for the WIPP has been prepared (DOE, 1988b). The plan describes measures to be taken in the event of an on-site or off-site emergency, including transportation emergencies. The plan generally requires that transportation accident response be handled by the waste shipper with assistance as necessary by the DOE, and local/State authorities.

The DOE has undertaken an extensive public information program for persons and authorities in the 23 affected States and Indian tribal governments that are along proposed TRU waste transportation routes. These individuals and authorities have been informed of the potential hazards of the wastes. As part of this notification, public awareness tours have been (and are being) conducted (SEIS Appendix H). This tour includes a display that explains the WIPP, the types of waste, the transportation routes, and includes a model of the TRUPACT-II container. The public awareness tour has been completed through 29 municipalities along the route from Idaho Falls, Idaho, to Carlsbad, New Mexico. The tour will be conducted along the route from Savannah River, South Carolina, to Carlsbad, New Mexico during 1989. Additionally, the tour will complete the remaining routes before waste would be transported along those routes. The DOE also displays the exhibit to various interstate agencies (e.g., Western Interstate Energy Board, Southern States Energy Board, and the Western Governors' Association). Finally, the exhibit has been displayed at various conferences (e.g., Waste Management 1988, Texas Emergency Managers Conference, American Chemical Society, and others), as appropriate.

State emergency plans from the 23 affected States have been reviewed by the DOE to ensure that 1) a State representative with radiological training would be a responder should an accident occur, and 2) the responsible State contact would activate the DOE Radiological Assistance Program. This is a nationwide program that provides that DOE personnel assist on the scene of any accident involving radioactive materials.

Communities along the approved transportation routes have been offered assistance in developing emergency plans. The DOE has answered questions and provided educational materials to communities that have requested assistance.

The DOE has developed a program that offers to train State, local, and Indian tribal police and emergency personnel in the proper procedures to be followed in the event of a transportation accident. The emergency procedures and responses described in Subsection 6.11 of the FEIS are a summary of the procedures that are taught in the training sessions. These are detailed in "The First Responders Course," the coursebook used in the training sessions (DOE, nd). To date, 2,417 firemen, policemen, and emergency medical personnel in the States of Idaho, Utah, Wyoming, Colorado, and New Mexico have been trained. State personnel along the route from Savannah River to the WIPP (South Carolina, Alabama, Georgia, Mississippi, Louisiana, and Texas) will be trained in 1989. Personnel from the remaining 12 states along the transportation routes are scheduled for training prior to the transport of waste through those States. Training includes an eight-hour course for personnel selected by the State to be first responders. Furthermore, instructional materials are provided to the State, enabling training of additional personnel by the States, as required.

The DOE has developed a transportation satellite tracking and communication system. This system has been designed, in part, to enhance emergency response capabilities. Emergency response would be faster because the location of each waste shipment is constantly tracked. One feature of the system is an emergency checklist that provides precautions to be taken in the case of an accident that results in the release of a hazardous substance. This information is specific to the material being transported.

The emergency preparedness program for the WIPP also includes the training of local hospital staff. A Memorandum Of Understanding has been agreed to by the DOE and the Guadalupe Medical Center in Carlsbad, New Mexico, and the Lea Regional Hospital in Hobbs, New Mexico. The purpose is to provide for 1) emergency equipment to be loaned to the two hospitals and 2) training of hospital staff to handle accident victims who have been exposed to radioactivity. Emergency equipment, such as decontamination table tops and decontamination kits, have been supplied to the two hospitals. The DOE is evaluating medical training groups with the medical expertise to handle contaminated accident victims. Upon completion of the evaluation and the selection process, the medical training of local hospital staff will take place. Additional details are included in Appendix C.

2.9 ENVIRONMENTAL MONITORING PROGRAMS

The DOE continues to conduct comprehensive environmental monitoring programs. Since the 1980 FEIS, these programs have been designed to characterize environmental baseline conditions at the WIPP and include:

- Radiological Baseline Program
- Ecological Monitoring Program
- Cooperative Raptor Research Program.

The scope of each of these studies is described in this subsection. The results of these studies are included in SEIS Subsections 4.1 and 5.1.

2.9.1 Radiological Baseline Program (RBP)

The Radiological Baseline Program (RBP) was initiated in 1984 to establish a statistically sound base of radiological data against which operational radiation measurements can be assessed. The RBP consists of five subprograms:

1) Atmospheric Radiation Baseline. This includes eight low-volume air sampling stations where airborne particulates are continuously collected and analyzed for radioactivity and seven high-volume air sampling stations where airborne particulates are collected intermittently.

2) Ambient Radiation Baseline. This includes 44 stations with thermoluminescent dosimeters and one station with a high-pressure ionization chamber to monitor penetrating radiation.

3) Terrestrial Radiation Baseline. This includes 37 stations where soil samples are collected.

4) Hydrologic Radiation Baseline. This includes 10 stations where surface water is collected (bottom sediments are also collected at four of these stations) and 23 wells where groundwater is collected.

5) Biotic Baseline. This includes the sampling of flora, as well as fauna, including small mammals, cattle, fish, and birds.

Radiochemical analysis for the RBP includes not only those radionuclides present in the waste but also radionuclides present in fallout and natural radioactivity. All major environmental media potentially affected by WIPP activities are sampled. Results of the RBP are presented and discussed in the annual WIPP Environmental Monitoring Reports (Reith et al., 1986; Banz et al., 1987; and Flynn, 1988). To date, RBP results are within the ranges of environmental radioactivity in the region of the WIPP expected by the National Council on Radiation Protection and Measurements (NCRPM, 1975, 1976) and Federal agencies (DOE, 1980).

2.9.2 Ecological Monitoring Program (EMP)

The EMP is the functional successor to the WIPP Biology Program that was initiated in 1975 to perform baseline nonradiological ecological studies prior to the start of WIPP construction. WIPP Biology Program results are reported in Subsection 7.1 of the FEIS. The EMP focuses on the vegetation and animal communities immediately surrounding the site and on the ecological parameters most likely to reflect the impact of construction and operational activities. The EMP consists of six subprograms:

- Meteorology. Temperature, relative humidity, barometric pressure, precipitation, and wind speed and direction are monitored continuously at the site.

- Air Quality. Atmospheric gases (hydrogen sulfide, sulfur dioxide, carbon monoxide, ozone, and nitrogen oxides) are continuously monitored at the site.

- Water Quality. Surface water, groundwater, and sediments are sampled periodically to determine the impact of WIPP construction.

- Aerial Photography. Aerial photographs are taken twice a year to document changes in the extent of land use and habitat disturbance.

- Vertebrate Census. Breeding bird and small mammal populations are surveyed annually to monitor for WIPP-related changes in population densities.

- Salt Impact Studies. This subprogram has four components:

    1) Surface Photography. Surface photographs are taken semiannually in each permanent monitoring plot to document alteration of habitat structure.

2) Soil Chemistry. Soil samples are collected at three depths (0 to 0.8 inch, 11.8 to 17.7 inches, and 23.6 to 29.5 inches) and are analyzed for direct evidence of salt-related chemical changes in the soil.

3) Soil Microbiota. Microbial activity levels and decomposition rates are monitored in recognition of the role these organisms play in maintaining energy flow through the ecosystem and their sensitivity to chemical changes in the soil.

4) Vegetation Survey. Foliar cover, species composition, and the density of annual species are monitored for indications of salt impacts on native vegetation in the ecosystem.

In general, the EMP has shown few adverse environmental impacts from the construction of the WIPP. Results of the EMP have been published in the Ecological Monitoring Program Reports (Reith et al., 1985; Fischer et al., 1985; Fischer, 1987, 1988).

2.9.3 Cooperative Raptor Research and Management Program

In 1985, the Los Medanos Cooperative Raptor Research and Management Program was initiated under the cosponsorship of the DOE, the BLM, and the Living Desert State Park. One goal of the study, conducted by researchers from the University of New Mexico, is to evaluate the impacts of WIPP activities on the breeding success of raptors (e.g., hawks and owls), of which some species are found in unusual abundance in the vicinity. Experiments are also being conducted to determine how these impacts may be mitigated.

Study results from 1986 (Bednarz, 1987) indicate that adverse impacts on nesting success resulting from human intrusion during critical times in the nesting cycle are measurably reduced by slight modification of field-work schedules to accommodate nesting activities. When nests have been found in locations potentially threatened by a nearby work area (such as a well pad), the Regulatory and Environmental Programs Section (REPS) at the WIPP has been notified and the scheduled use of the work area examined. Whenever possible, work schedules have been, and will be, modified to minimize impacts on the nests.

2	2-23	References	(1) Third citation date, 1989, should read 1988 and last line should read "Carlsbad, New Mexico, (draft)." (2) Fifth citation, second line, Revision 5 should read Revision 4.

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3) Soil Microbiota. Microbial activity levels and decomposition rates are monitored in recognition of the role these organisms play in maintaining energy flow through the ecosystem and their sensitivity to chemical changes in the soil.

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REFERENCES FOR SECTION 2

Banz et al. (I. Banz, P. Bradshaw, J. S. Cockmen, N. T. Fischer, J. K. Prince, A. Rodriguez, and D. W. Uhland), 1987. Annual Site Environmental Monitoring Report for the Waste Isolation Pilot Plant Calendar Year 1986, DOE/WIPP 87-002, Waste Isolation Pilot Plant, Carlsbad, New Mexico.

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WEC (Westinghouse Electric Corporation), 1988. RCRA Compliance at the Department of Energy's Waste Isolation Pilot Plant, prepared by IT for Westinghouse, Albuquerque, New Mexico.

3.0 DESCRIPTION OF THE PROPOSED ACTION AND ALTERNATIVES

This section describes the Proposed Action, the alternative of No Action, the alternative of conducting only those tests that can be performed without the emplacement of waste underground until there is a determination of compliance with regulatory requirements. The alternative of either conducting no tests involving wastes or conducting tests with simulated, nonradioactive wastes was rejected as unreasonable because it would not provide sufficient data for assessing compliance with applicable standards. The Proposed Action is to proceed with the WIPP as described in the 1980 FEIS (FEIS Alternative 2, the Authorized Alternative, in Subsection 3.6.3.1) while incorporating certain proposed modifications as discussed below.

3.1 PROPOSED ACTION

The Proposed Action is to proceed with a phased approach to determine whether the WIPP should become a repository for the disposal of TRU waste.

To put this SEIS Proposed Action in context, it should be noted that a phased decision-making process relative to construction and operation of the WIPP has been pursued since the TRU waste disposal program's inception. Generally, this process began with site selection and characterization; proceeded through site design and validation to construction; would continue, if appropriate, with the Test Phase; and could conclude, if appropriate, with the Disposal Phase.

The DOE's decision to proceed with the WIPP project at a location in southeastern New Mexico followed a NEPA review that culminated in the public distribution of the FEIS in 1980. A Record of Decision (DOE, 1981) was signed, and Alternative 2 of the FEIS was selected in early 1981. That alternative called for the development of the authorized WIPP, consisting of surface and underground facilities designed to emplace approximately 6.2 million ft^3 of CH TRU waste and 250,000 ft^3 of RH TRU waste in a 100-acre mined repository. The construction of a 20-acre underground area for short-term experiments to analyze and respond to technical questions regarding the disposal of high-level waste was also part of the decision. In order to provide final site validation and to verify the analyses used in the design of the underground facility, the construction of the WIPP was to be preceded by construction of two deep shafts and underground geologic experimentation. These experiments were proposed to measure rock response and to conduct tests with nonradioactive materials. The Preliminary Site and Design Validation Program and the construction of most WIPP facilities have been completed.

NCRPM (National Council on Radiation Protection and Measurements), 1975. Natural Background Radiation in the United States, NCRP Report 45.

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3.1.1 Changes to the Proposed Action and New Information or Circumstances

This subsection describes specific proposed changes not covered in the 1980 FEIS, as well as new circumstances and information since 1980. These changes have been factored into the impact analyses in this SEIS.

- Expanding the Proposed Action to include TRU wastes from two additional sites. The 1980 FEIS analyzed the disposal of defense program TRU wastes only from the Rocky Flats Plant in Colorado and the Idaho National Engineering Laboratory in Idaho (DOE, 1980). Since that time, the DOE has proposed that retrievable and newly-generated TRU wastes from the Savannah River Plant in South Carolina (DOE, 1988a) and the Hanford Reservation in Washington (DOE, 1987a) also be disposed of at the WIPP. The WIPP is therefore proposed as a permanent repository for TRU wastes from the Idaho National Engineering Laboratory, Rocky Flats Plant, Savannah River Plant, and Hanford Reservation.

  The DOE may propose that TRU waste stored and/or generated by six additional facilities should be transferred to the WIPP for permanent emplacement. Appropriate site-specific NEPA documentation would be prepared for such a proposal for each of the six facilities: Los Alamos National Laboratory, New Mexico; Nevada Test Site, Nevada; Oak Ridge National Laboratory, Tennessee; Argonne National Laboratory-East, Illinois; Lawrence Livermore National Laboratory, California; and Mound Laboratory, Ohio. However, the DOE's present knowledge of waste inventories makes it possible to assess in this SEIS the impacts of transporting to, receiving, and permanently emplacing wastes at the WIPP from all six potential sources. Therefore, even though not part of the current Proposed Action, this SEIS evaluates the cumulative impacts of disposing waste from these six additional facilities at the WIPP, should the DOE propose to do so at some future time.

- Changes in the volume of the TRU waste inventory. In 1980, it was contemplated that approximately 6.2 million ft^3 of CH and 250,000 ft^3 of RH TRU waste could be disposed of in the WIPP. The WIPP as designed (i.e., covering 100 acres) would be able to accommodate this volume of TRU waste. Current estimates indicate that approximately 5.6 million ft^3 of CH TRU and 93,000 ft^3 of RH TRU waste are in retrievable storage at 10 generator/storage facilities or will be newly-generated by these facilities through the year 2013, the projected operating life of the WIPP (Tables 3.1 and 3.2). This lesser volume is currently estimated because of an improvement in recordkeeping and inventory sampling, a change in the definition of TRU waste (SEIS Appendix B), changes to the WIPP Waste Acceptance Criteria (WAC) (SEIS Subsection 2.3 and Appendix A), and expected facility process modifications.

  This SEIS assesses the impacts of the WIPP using the volume limits of 6.2 million ft^3 of CH waste and 250,000 ft^3 of RH TRU waste to set an upper limit on the potential impacts of filling the WIPP repository to its design capacity. The WIPP design capacity is sufficient to encompass TRU waste generated from new or planned defense-related facilities (e.g., Special Isotope Separation Facility). Should

TABLE 3.1 Estimated quantity of CH TRU waste in retrievable storage or projected to be generated through the year 2013[a]

Generator or storage facility	Estimated volume (ft^3)		
	Retrievably stored CH TRU waste[b]	Newly-generated CH TRU waste[c]	Total
Idaho National Engineering Laboratory[d]	1,073,686	9,923	1,083,609
Rocky Flats Plant[e]	0	2,037,582	2,037,582
Hanford Reservation[d]	293,247	537,762	831,009
Savannah River Plant[d]	91,463	615,947	707,410
Los Alamos National Laboratory[d]	250,905	302,253	553,158
Nevada Test Site[d]	21,294	0	21,294
Oak Ridge National Laboratory[d]	19,176	41,953	61,129
Argonne National Laboratory-East[e]	0	3,814	3,814
Lawrence Livermore National Laboratory[e]	0	259,346	259,346
Mound Laboratory[e]	0	40,046	40,046
Totals	1,749,771	3,848,626	5,598,397

[a] Estimated volumes correspond to the Integrated Data Base for 1987: Spent Fuel and Radioactive Waste Inventories, Projects and Characterizations, DOE/RW-0006, Revision 3(DOE, 1987b). Volumes of waste used for the environmental analysis in this SEIS are higher and are based on the WIPP design capacity.

[b] From Table 3.5, (DOE, 1987b).

[c] From Table 3.16, (DOE, 1987b).

[d] These sites have been designated as TRU waste storage sites.

[e] These sites generate but do not store TRU waste.

TABLE 3.2 Estimated quantity of RH TRU waste in retrievable storage or projected to be generated through the year 2013[a]

Generator or storage facility	Estimated volume (ft^3)		
	Retrievably-stored RH TRU waste[b]	Newly-generated RH TRU waste[c]	Total
Idaho National Engineering Laboratory[d]	989	4,873	5,862
Hanford Reservation[d]	848	28,604	29,452
Los Alamos National Laboratory[d]	1,024	212	1,236
Oak Ridge National Laboratory[d]	45,484	10,594	56,078
Argonne National Laboratory-East[e]	0	283	283
Totals	48,345	44,566	92,911

[a] Estimated volumes correspond to the Integrated Data Base for 1987: Spent Fuel and Radioactive Waste Inventories, Projects and Characterizations, DOE/RW-0006, Revision 3 (DOE, 1987b). The estimated volumes of waste used for the environmental analysis in this SEIS are higher and are based on the design capacity of the WIPP.

[b] From Table 3.5, (DOE, 1987b).

[c] From Table 3.16, (DOE, 1987b).

[d] These sites have been designated as TRU waste storage sites.

[e] This site generates but does not store TRU waste.

additional TRU waste inventory be proposed for disposal at the WIPP in the future, further NEPA documentation would be required.

- Changes in the composition of the TRU waste radioactive inventory to include high-curie and high-neutron waste, and to eliminate high-level waste experiments (SEIS Subsection 3.1.1.1 and Appendix B). Plutonium-238 (Pu-238) and, to a lesser extent, americium-241 are the major contributors to the total radionuclide content of CH TRU waste. Pu-238 waste has a higher curie content and heat-generating capacity than wastes assumed in the FEIS analyses. The FEIS did not consider neutron dose rates; a small amount of such neutron-emitting wastes containing californium-252 (Cf-252) may be disposed of at the WIPP. Experiments using high-level wastes are no longer proposed for the WIPP.

- Consideration of the hazardous chemical constituents of the inventory (SEIS Subsection 3.1.1.2). It is estimated that approximately 60 percent of the TRU waste that may be emplaced in the WIPP contains hazardous chemical constituents. However, the hazardous chemical constituents of this radioactive mixed waste constitute only a small fraction of the total waste volume and consist primarily of metallic lead from radiation shielding and residual quantities of organic solvents.

- Changes in the modes of transportation (SEIS Subsection 3.1.1.3). In the FEIS, it was anticipated that a mixed transport mode (75 percent train and 25 percent truck) would be used. This SEIS considers transport by truck (100 percent) or "maximum" train mode (i.e., train transport from eight facilities and truck transport from Los Alamos National Laboratory, and the Nevada Test Site, as they lack railheads). The use of 100-percent truck transportation is currently expected; the train option could be used in combination with trucks in the future and, thus, is analyzed as an option in this SEIS.

- Changes in the waste packaging (SEIS Subsection 3.1.1.3). The design of the CH TRU waste package has changed from a Type A (TRUPACT-I) container in 1980 to a Type B (TRUPACT-II) container to be certified by the NRC.

- Implementation of a Test Phase (SEIS Subsection 3.1.1.4). The technical focus of the proposed Test Phase is 1) to reduce uncertainties associated with two primary factors that may affect repository performance: gas generation and brine inflow (SEIS Subsection 3.1.1.4), and 2) to demonstrate waste handling operations. For purposes of analysis, this SEIS assumes that a maximum of 10 percent of the WIPP TRU waste capacity might be retrievably emplaced during the Test Phase. The actual volumes may be less but the impacts would be bounded by the analysis in this SEIS.

The preceding changes (or new circumstances) are described in the following subsections in greater detail.

3.1.1.1 Transuranic Radionuclide Inventory. The types and quantities of radionuclides in the TRU waste that may be disposed of in the WIPP are collectively termed the "radionuclide waste inventory." Proposed changes in the TRU waste radionuclide inventory involve the amount and type of radioactive material to be emplaced. These proposed changes warrant discussion because they relate directly to the analyses of the potential environmental consequences of transporting waste to the WIPP (SEIS Subsection 5.2.2), WIPP operations (SEIS Subsection 5.2.3), and WIPP performance after closure (SEIS Subsection 5.4). These changes are described below and are further documented in the draft Final Safety Analysis Report (FSAR), Waste Isolation Pilot Plant (DOE, 1988b).

Since the publication of the FEIS, techniques have been developed to better characterize the TRU waste generated at DOE defense program facilities. Sampling and measurement of wastes by radiography, nuclear assaying, and other methods, and more stringent tracking and recordkeeping requirements have resulted in a better estimate of defense program TRU waste. In addition, the definition of TRU waste has changed. Prior to 1982, TRU waste was defined as having greater than 10 nCi/g of alpha-emitting radionuclides; TRU waste is presently defined as having greater than 100 nCi/g of alpha-emitting radionuclides and a half-life greater than 20 years. This redefinition was accepted in August 1982 and was formalized in DOE Order 5820, "Radioactive Waste Management," in February 1984. This change has resulted in the reclassification of certain TRU wastes (i.e., less than 100 nCi/g) to low-level waste, which the DOE does not propose to dispose of in the WIPP. The EPA and NRC have also adopted the reclassification of TRU wastes.

The waste characteristics given in Appendix E of the FEIS were based on TRU waste from the Rocky Flats Plant in Colorado because this waste was representative of the total TRU waste proposed for disposal at the WIPP in 1980. The SEIS analyses are based on the more current waste characterization data reported for each generator facility in the draft FSAR. These data indicate that surface dose rates, curie content, total plutonium content, and fissile material for CH TRU wastes have increased over comparable estimates in the FEIS (Table 3.3); except for surface dose rates, similar increases were noted for RH TRU waste. The TRU waste that may be shipped to the WIPP typically contains a variety of plutonium isotopes, as described in the FEIS (Appendix E). The average plutonium isotopic content of the waste as reported in the FEIS, is compared to those in the draft FSAR and Appendix B of the SEIS. The plutonium contents reported in the draft FSAR are generally greater than those reported in the FEIS. The uranium content of the waste is also reported in the draft FSAR and in this SEIS and contributes about the same mass as plutonium.

Since publication of the FEIS, the DOE has determined that the radioisotopes plutonium-238 (Pu-238) and, to a lesser extent, americium-241 (Am-241) are the major contributors to the total radionuclide content of CH TRU waste, primarily due to waste generated at the Savannah River Plant in South Carolina (DOE, 1988a). This waste has a higher curie content and heat-generating capacity than the waste described in the FEIS analyses. The average Pu-238 content reported in the FEIS is 1.2 percent of the total radioactivity content of CH TRU waste. TRU waste from the Savannah River Plant increases the Pu-238 contribution to the radioactivity of all CH TRU waste to 17 percent. The higher proportion of Pu-238 and Am-241 in the total waste has modified the average radionuclide composition of the "source term" (i.e., the actual amount of radioactivity potentially available for release) used to evaluate radiation dose consequences in this SEIS. High-curie content waste would be subject to the same surface-dose-equivalent rate restrictions as other wastes; therefore, no unique handling, storage procedures, or precautions would be required for the high-curie wastes.

TABLE 3.3. Summary of average TRU waste characteristics

	CH TRU waste		RH TRU waste	
Criterion	FEIS[a]	FSAR[b]	FEIS	FSAR
Surface dose rate[c]				
Canister			200-100,000	30,000
Drum	3.1	14		
DOT Type 7A box	1	14		
DOT Type 7A box	0.8	0.8		
Curies[e]				
Canister			512	37
Drum	3.4	20.6		
DOT Type 7A box	5.5	77		
Total plutonium[f]				
Canister			12.8	121
Drum	8	15.5		
DOT Type 7A box	13	86.3		
Fissile materials[g]				
Canister			12	110
Drum	7.5	17		
DOT Type 7A box	12.2	90		

3 3-7 Table 3.3, Under thermal power, the number 60 in the FEIS CH TRU column should appear under the FEIS RH TRU waste column.

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[a] DOE, 1980.

[b] DOE, 1988b.

[c] The radiation exposure rate at the outside surface of the container in mrem/hr.

[d] The heat generating capacity of the radionuclides in watts (W).

[e] The special unit of activity in curies; one curie (Ci) equals 3.7×10^{10} nuclear transformations per second.

[f] Total plutonium mass in grams (g).

[g] Expressed as the plutonium-239 (Pu-239) equivalent fissile content in grams (g).

the potential environmental consequences of transporting waste to the WIPP (SEIS Subsection 5.2.2), WIPP operations (SEIS Subsection 5.2.3), and WIPP performance after closure (SEIS Subsection 5.4). These changes are described below and are further documented in the draft Final Safety Analysis Report (FSAR), Waste Isolation Pilot Plant (DOE, 1988b).

Since the publication of the FEIS, techniques have been developed to better characterize the TRU waste generated at DOE defense program facilities. Sampling and measurement of wastes by radiography, nuclear assaying, and other methods, and more stringent tracking and recordkeeping requirements have resulted in a better estimate of defense program TRU waste. In addition, the definition of TRU waste has changed. Prior to 1982, TRU waste was defined as having greater than 10 nCi/g of alpha-emitting radionuclides: TRU waste is presently defined as having greater than 100 nCi/g of alpha-emitting [illegible] This redefinition was accept[illegible] "Radioactive Waste Ma[illegible] reclassification of certain TRU wastes [illegible] which the DOE does not propose to dispose of in the WIPP. The EPA and NRC have also adopted the reclassification of TRU wastes.

The waste characteristics given in Appendix E of the FEIS were based on TRU waste from the Rocky Flats Plant in Colorado because this waste was representative of the total TRU waste proposed for disposal at the WIPP in 1980. The SEIS analyses are based on the more current waste characterization data reported for each generator facility in the draft FSAR. These data indicate that surface dose rates, curie content, total plutonium content, and fissile material for CH TRU wastes have increased over comparable estimates in the FEIS (Table 3.3); except for surface dose rates, similar increases were noted for RH TRU waste. The TRU waste that may be shipped to the WIPP typically contains a variety of plutonium isotopes, as described in the FEIS (Appendix E). The average plutonium isotopic content of the waste as reported in the FEIS, is compared to those in the draft FSAR and Appendix B of the SEIS. The plutonium contents reported in the draft FSAR are generally greater than those reported in the FEIS. The uranium content of the waste is also reported in the draft FSAR and in this SEIS and contributes about the same mass as plutonium.

Since publication of the FEIS, the DOE has determined that the radioisotopes plutonium-238 (Pu-238) and, to a lesser extent, americium-241 (Am-241) are the major contributors to the total radionuclide content of CH TRU waste, primarily due to waste generated at the Savannah River Plant in South Carolina (DOE, 1988a). This waste has a higher curie content and heat-generating capacity than the waste described in the FEIS analyses. The average Pu-238 content reported in the FEIS is 1.2 percent of the total radioactivity content of CH TRU waste. TRU waste from the Savannah River Plant increases the Pu-238 contribution to the radioactivity of all CH TRU waste to 17 percent. The higher proportion of Pu-238 and Am-241 in the total waste has modified the average radionuclide composition of the "source term" (i.e., the actual amount of radioactivity potentially available for release) used to evaluate radiation dose consequences in this SEIS. High-curie content waste would be subject to the same surface-dose-equivalent rate restrictions as other wastes; therefore, no unique handling, storage procedures, or precautions would be required for the high-curie wastes.

TABLE 3.3. Summary of average TRU waste characteristics

	CH TRU waste		RH TRU waste	
Criterion	FEIS[a]	FSAR[b]	FEIS	FSAR
Surface dose rate[c]				
Canister			200-100,000	30,000
Drum	3.1	14		
DOT Type 7A box	1	14		
Thermal power[d]				
Canister				70
	60			
Drum	0.5	0.5		
DOT Type 7A box	0.8	0.8		
Curies[e]				
Canister			512	37
Drum	3.4	20.6		
DOT Type 7A box	5.5	77		
Total plutonium[f]				
Canister			12.8	121
Drum	8	15.5		
DOT Type 7A box	13	86.3		
Fissile materials[g]				
Canister			12	110
Drum	7.5	17		
DOT Type 7A box	12.2	90		

[a] DOE, 1980.

[b] DOE, 1988b.

[c] The radiation exposure rate at the outside surface of the container in mrem/hr.

[d] The heat generating capacity of the radionuclides in watts (W).

[e] The special unit of activity in curies; one curie (Ci) equals 3.7 x 10^{10} nuclear transformations per second.

[f] Total plutonium mass in grams (g).

[g] Expressed as the plutonium-239 (Pu-239) equivalent fissile content in grams (g).

Similarly, Am-241 concentrations presented in this SEIS are higher than those in the 1980 FEIS.

The FEIS did not address neutron dose rates because neutron emitters were not identified in the waste that might be shipped to the WIPP. However, the DOE may in the future propose that the Oak Ridge National Laboratory in Tennessee contribute a small amount of waste to the WIPP containing californium-252 (Cf-252), which decays by spontaneous fission (DOE, 1988b). Almost 0.76 percent of the total RH TRU waste radioactivity would be composed of Cf-252. Neutron-emitting wastes would be subject to the same surface dose equivalent rate restrictions as other wastes; therefore, no unique handling, storage procedures, or precautions would be required for the high-neutron waste.

The FEIS discussed high-level waste experiments in Subsections 5.1.3, 6.3.3, 6.5.3, and 8.9, (see also Appendix E). An isolated area of the WIPP underground facility was to be dedicated to experiments to determine the long-term behavior of various waste forms in bedded salt. The FEIS suggested that much of this waste would be specifically prepared for experiments and would produce high levels of heat and radiation.

The need for conducting high-level waste experiments at the WIPP has been reassessed, and the DOE has decided to eliminate this aspect of the WIPP project. This decision was based principally on the decision under the Nuclear Waste Policy Amendments Act of 1987 to discontinue further characterization of the Deaf Smith County, Texas, bedded salt site for the disposal of commercial high-level waste. Therefore, the DOE is not proposing to emplace high-level waste in the WIPP for experimental purposes.

3.1.1.2 Hazardous Chemical Constituents. Radioactive waste that also contains hazardous chemical constituents is termed radioactive mixed waste. The FEIS did not separately address the hazardous waste component of TRU mixed waste, even though it was known that it would comprise a certain portion of the total waste to be shipped to the WIPP. This SEIS includes analyses of the potential environmental consequences of the hazardous chemical constituents in the TRU mixed waste. Until May 1, 1987, the DOE considered mixed waste to be exempt from the regulations promulgated under the Resource Conservation and Recovery Act (RCRA) because the DOE believed these wastes to be within the definition of radioactive "byproduct material" regulated under the Atomic Energy Act and, therefore, excepted from the definition of "solid waste" in the RCRA. On May 1, 1987, the DOE published an Interpretive Rule at 10 CFR Part 962 (52 FR 15937) indicating that the hazardous constituents of its mixed waste were not "byproduct material" and, therefore, were subject to regulation under the RCRA. Accordingly, mixed waste that qualifies as hazardous waste under the RCRA is subject to dual regulation under the RCRA and the AEA (SEIS Subsection 10.2.1).

Until recently, few records were required to document the hazardous chemical constituents in the TRU waste generated by DOE facilities. Because of the complex waste matrices and potential for unacceptable radiation exposure to personnel, TRU mixed waste has been characterized on the basis of the processes used in generating the waste and limited sampling of stored drums. The requirements of strict product quality and concerns for safety in handling radioactive material demand highly structured production and research activities. Accordingly, information on potential hazardous constituents is obtainable through process knowledge.

The 10 defense program facilities that may transport waste to the WIPP have conservatively characterized their TRU mixed waste to facilitate preparation of the permit application to operate the WIPP as an interim status facility under the RCRA. This information was reported by WEC (1989) and represents a conservative upper bound in classifying the waste.

The identification of the hazardous chemical constituents in CH TRU mixed waste is based on newly-generated waste from the Rocky Flats Plant in Colorado and waste from the Rocky Flats Plant that is currently in retrievable storage at the Idaho National Engineering Laboratory in Idaho. It is estimated that the waste generated by the Rocky Flats Plant, (including Rocky Flats waste stored in Idaho), represents approximately 50 percent of the total CH TRU waste by volume that might be disposed of at the WIPP. The Rocky Flats Plant generates many different forms of waste from a variety of processes. Based on data submitted by the generators of TRU mixed waste (WEC, 1989), other facilities generate smaller quantities of TRU mixed waste, fewer waste forms, and waste that contains a narrower range of hazardous chemical constituents. Also, no hazardous chemical constituents were reported by other facilities that were not reported by the Rocky Flats Plant and the Idaho National Engineering Laboratory.

The CH TRU waste is categorized into waste "forms" on the basis of the physical characteristics of the materials in the waste. Each waste form must be certified by the DOE for compliance with the WIPP WAC (SEIS Subsection 2.4.1 and Appendix A) before shipment to the WIPP. The waste forms that have been identified by the Rocky Flats Plant as containing hazardous chemical constituents are cemented and uncemented aqueous and organic wastes, immobilized process and laboratory solids, combustible waste, metal and filter waste, inorganic solids, and leaded rubber waste. Detailed descriptions of these waste forms, provided in SEIS Appendix B, indicate that the majority of the organic solvents are present in residual quantities from the cleaning of equipment, plastics, glassware, and filters. A major constituent in CH TRU mixed waste is lead, which is present predominantly as shielding, glove box parts, and lead-lined gloves and aprons.

The types and estimated maximum concentrations of hazardous chemical constituents in the CH TRU mixed waste forms are provided in Table 3.4. These concentrations, as estimated by the Rocky Flats Plant (Rockwell International, 1988), represent the maximum concentrations expected in the waste forms. The DOT requires generators to document the concentrations of hazardous materials over reportable quantities (49 CFR Part 172.101) on the shipping documents that accompany the waste during transport; therefore, the Rocky Flats Plant has reported the maximum expected concentrations based on process knowledge. The data indicate a broad range of concentrations of the various constituents, both within and between waste forms. They also indicate that the majority of the waste forms contain less than 1 percent by weight of any of the identified hazardous chemical constituents.

TABLE 3.4 Estimated maximum concentrations of hazardous chemical constituents in TRU mixed waste from the Rocky Flats Plant[a]

Hazardous chemical[c] constituent	Waste form[b]							
	Aqueous sludges[d]	Organic sludges[d]	Process and laboratory solids[e]	Combustible waste	Metal waste	Filter waste	Inorganic solids	Leaded rubber
1,1,1-trichloroethane	75	150,000	200	2,000	15	150	900	0
Carbon tetrachloride	25	50,000	25	750	10	150	100	0
1,1,2-trichloro-1,2,2-trifluoroethane	100	50,000	200	1,500	75	100	8,000	0
Methylene chloride	700	0	100	750	200	50	700	0
Methyl alcohol	25	0	15	0	0	0	0	0
Xylene	50	0	50	0	0	0	0	0
Butyl alcohol	10	0	10	0	0	0	0	0
Cadmium	10	0	0	0	0	0	0	0
Lead	10	0	400	10	$1x10^6$	0	0	$6x10^5$

[a] Estimated maximum concentrations in milligrams per kilogram (mg/kg) (Rockwell International, 1988).

[b] Waste forms are described in detail in SEIS Appendix B.

[c] The hazardous chemical constituents were determined by knowledge of the processes used in generating the waste. The estimated maximum concentrations represent conservative (i.e., overestimated) quantities that may be present in the specific waste forms. No analytical data are available for the hazardous chemical constituents in these waste forms.

[d] Cemented and uncemented sludges.

[e] Neutralized and immobilized (cemented) solids.

RH TRU waste is a much smaller portion of the total waste that may be sent to the WIPP (SEIS Subsection 2.3). The Oak Ridge National Laboratory generates more than 90 percent of the RH TRU waste and has reported that the two major forms of RH TRU mixed waste are solids and sludges (SEIS Appendix B) (DOE, 1987b). The primary hazardous chemical constituent in the RH TRU mixed waste is lead that has been used as shielding. Trace quantities of mercury, barium, chromium, and nickel have also been reported in some of the sludges.

3.1.1.3 Transportation of TRU Waste to the WIPP. Chapter 6 of the 1980 FEIS described the main features of transporting radioactive TRU waste to the WIPP, including the DOT and NRC regulations governing transport, the packages and packaging systems to be used for the waste, and the typical transportation modes and routes. Since that time, there have been changes in the waste packaging systems and the transportation modes and routes; these changes directly affect the analyses of the environmental consequences of waste transportation that are presented in SEIS Subsection 5.2.2.

This subsection describes the changes in the waste-packaging systems and transportation modes and routes. Additional details are provided in SEIS Appendices C and D. The 1980 FEIS defined "packaging" as the shipping container for radioactive waste and "package" as the shipping container and its radioactive contents. These same definitions apply to these terms when used in this SEIS.

Waste Transportation Packaging. Type B double-contained packagings are required for the transport of TRU waste containing over 20 curies of plutonium. In order to be certified by the NRC as Type B (10 CFR Part 71.73), a packaging must undergo evaluations related to normal transportation conditions and hypothetical accident scenarios, including:

1) Handling drop. A drop from a height of 3 ft onto a hard, unyielding surface.

2) Free drop. A drop from a height of 30 ft onto a hard, unyielding surface

3) Puncture. A drop from a height of 40 inches onto a pin that is 6 inches in diameter.

4) Thermal. Exposure to the environment of a fire with a temperature of 1,475 degrees Fahrenheit (°F) for 30 minutes.

5) Immersion. A submersion equivalent to the packaging being immersed under at least 3 ft of water for 8 hours.

The package must withstand these combined events without releasing more than a specified very small portion of the radioactive contents. Additional details on Type B requirements are provided in SEIS Subsection 10.2.6 and Appendix D. Table 3.5 shows the actual numbers of DOE tests performed against requirements.

TABLE 3.5 Minimum regulatory testing requirements vs. actual TRUPACT-II certification testing program

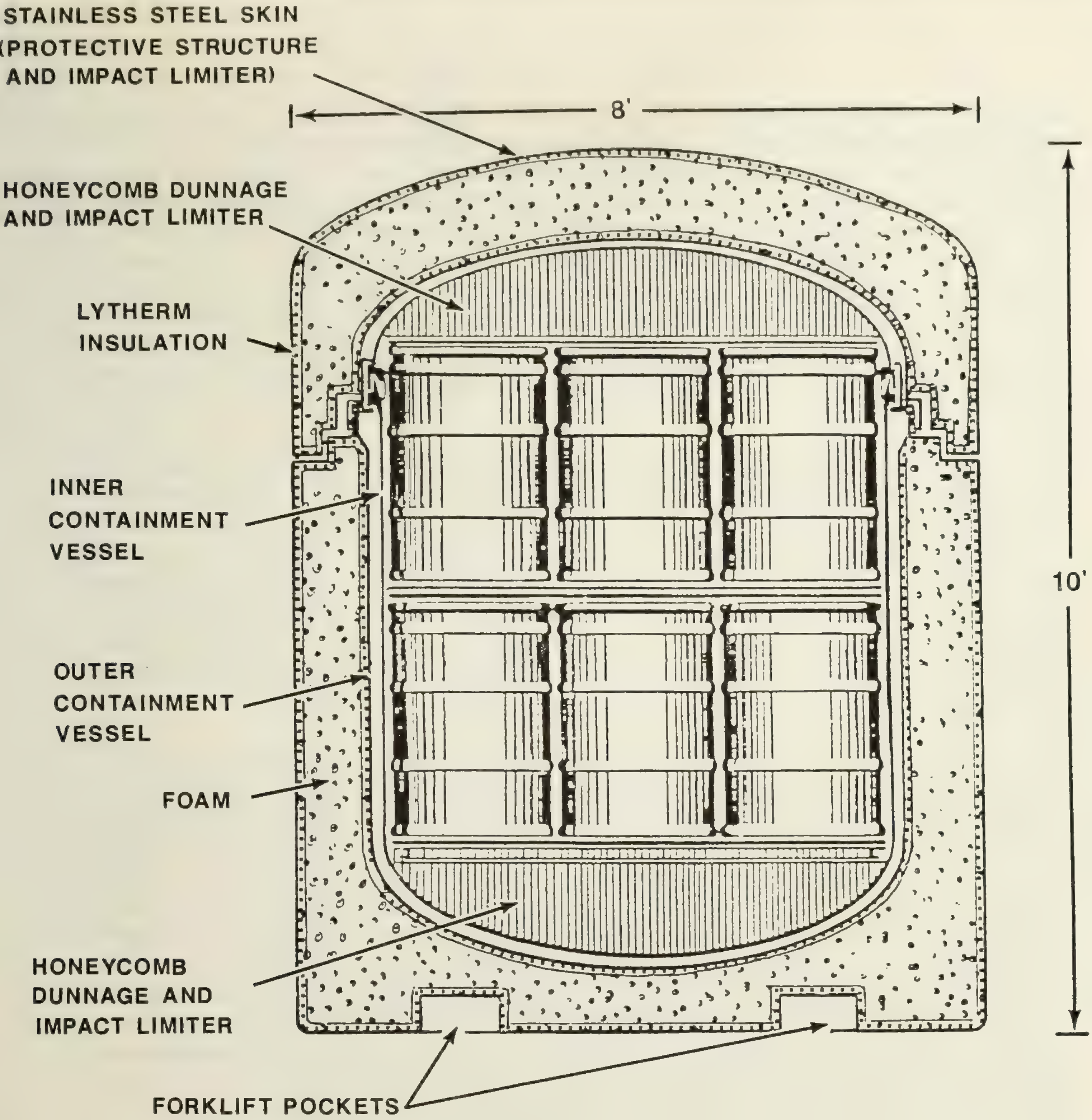
		Number of tests		
Test	Requirement[a]	Unit 1	Unit 2	Unit 3
3-ft drop	1	0	1	0
30-ft drop	1	3	3	3
40-inch pin punch	1	7	6	6
Thermal	1	1	1	1
Immersion	1	By analysis[b]	By analysis[b]	By analysis[b]

[a] From 10 CFR Part 71.73; requirements can be met by test or analysis.
[b] Note: One analysis used to support all three units.

The packaging intended for transporting CH TRU waste to the WIPP is the TRUPACT-II, a circular cylinder with a flat bottom and a domed top that is transported in an upright position. The major components of the TRUPACT-II (Figure 3.1) are a sealed inner stainless steel containment vessel within a sealed outer stainless steel containment vessel. Each containment vessel is non-vented and capable of withstanding a pressure of 50 pounds per square inch (psi). The overall dimensions of the TRUPACT-II are approximately 8 ft in diameter by 10 ft high; the inner containment vessel is approximately 6 ft in diameter by 6 ft high. The inner and outer containment vessels have removable lids that are held in place by banded lockrings and retainers. The outer containment vessel is also surrounded by approximately 10 inches of fire-retardant polyurethane foam acting as a thermal insulator and two 1/4-inch layers of ceramic fiber for additional thermal insulation.

On the outside of this foam and ceramic fiber, external to the containment, is a stainless steel shell that acts as a protective structure as well as an impact limiter. This multi-layered wall design increases the overall packaging strength and provides the ability to withstand potential accidents associated with transport. As a result of the protective functions of the foam, fiber, and outer shell, neither of the TRUPACT-II containers is expected to be breached by drops, punctures, or other penetrations.

Type A packagings will generally be used inside TRUPACT-II packaging for the transport of CH TRU waste to the WIPP. Type A packagings must meet the requirements of 49 CFR Part 178.350, including evidence that the design can withstand the normal conditions of transport as defined in 49 CFR Parts 173.465 and 173.466. Related evaluations involve exposure of the packaging to simulated rainfall, free fall, compression, and penetration.



NOT TO SCALE

FIGURE 3.1
CROSS SECTION OF TRUPACT-II

These Type A waste packagings to be transported within the TRUPACT-II are normally expected to be Type A 55-gal drums or standard waste boxes (SWBs). The 55-gal drums are constructed of 16-gauge steel and may have liners of 90-mil high-density polyethylene; the drums have removable lids retained by bolted rings while the liners have snap-fit lids or bolted rings. Each drum normally measures 24 inches in diameter by 35 inches high. The drums will be grouped into "7-packs" (seven drums banded together by metal banding or plastic stretch wrap). Each SWB will measure approximately 71 inches in diameter with two flat sides measuring 54 inches wide by 37 inches high (i.e., rectangular in shape with rounded ends). The drums and SWBs will have filtered vents. Each TRUPACT-II has the payload capacity for two 7-packs of drums or two SWBs.

Prior to being used to transport CH TRU waste, the TRUPACT-II will comply with appropriate Federal regulations including the NRC's requirements for packaging and transportation of radioactive material (10 CFR Part 71). It is anticipated that the NRC will issue a certificate of compliance for truck transport of the TRUPACT-II in mid-1989 after reviewing analyses and test results including the Type B events that were described previously. A decision to pursue certification for rail transport will be made after the DOE has fully evaluated the option of rail transport for TRU waste. Some design features of the TRUPACT-II (e.g., the tiedown system for attaching the packaging to a railcar) may have to be modified for rail transport.

The 1980 FEIS did not propose a specific type of packaging for transporting RH TRU waste to the WIPP, but implied that this packaging would comply with Type B requirements and would be shielded as necessary. The DOE is now developing the Nuclear Packaging 72B (NUPAC 72B) for the transportation of RH TRU waste. Fabrication and testing of this packaging are expected to be completed in the early 1990s. The NUPAC 72B (Figure 3.2) is designed with cylindrical outer and inner stainless steel containment vessels that will be transported horizontally. The outer containment vessel, or cask, measures approximately 41 inches in diameter by 11.8 ft in length by 4.4 inches in thickness, and the inner containment vessel measures approximately 32 inches in diameter by 11 ft in length by 0.4 inch in thickness. The outer and inner containment vessels will have 6.0-inch and 6.5-inch-thick steel lids at one end, respectively. The outer vessel wall includes approximately 1.9 inches of lead shielding. The two vessels provide the double containment required for radioactive materials containing more than 20 Ci of plutonium under 10 CFR Part 71.63. The NUPAC 72B will have stainless steel and polyurethane foam impact limiters on either end and a stainless steel thermal shield on the side. Within will be a carbon steel canister 121 inches long with an outside diameter of 26 inches. Within this canister the TRU waste will typically be contained in 55-gal drums, 30-gal drums, or similar containers.

Transportation Modes. The 1980 FEIS considered transportation of TRU waste to the WIPP by a combination of truck and rail transport (75 percent rail and 25 percent truck). The DOE currently proposes to use 100 percent truck transportation, but has not dismissed using rail transportation in the future. The basis of the proposal to use trucks is the greater accessibility to the site and greater control of the transportation system and routes.

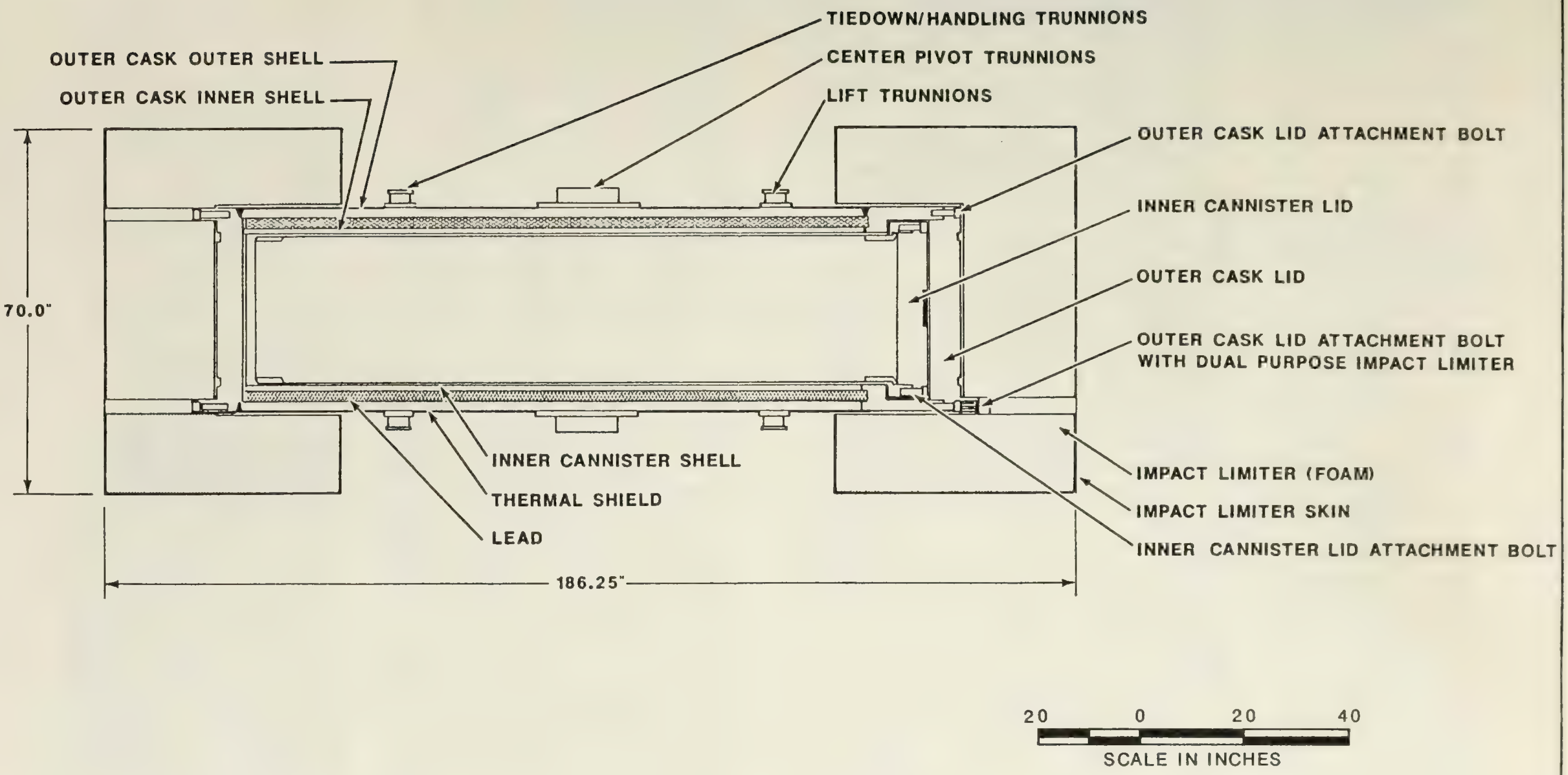


FIGURE 3.2
CROSS SECTION OF NUPAC 72B

This SEIS considers two transportation modes, truck transport and maximum rail transport. The truck transport mode assumes shipping TRU waste to the WIPP 100 percent by truck; the maximum rail transport mode assumes shipping the TRU waste to the WIPP by rail from eight defense program facilities that now have railroad access and by truck from the two defense program facilities that do not have railroad access. This approach bounds the impact from any combination of shipping modes that the DOE may select in the future for the TRU waste that may be disposed at the WIPP.

The TRU waste will be trucked to the WIPP in TRUPACT-II packagings mounted on low-boy trailers pulled by diesel powered tractors (Figure 3.3). These tractor-trailer combinations or rigs are similar to those now used for commercial purposes; however, they have been specially designed to carry three TRUPACT-II packagings per trailer, and they have other special features such as a two-way communications systems and road speed limiters (governors). In 1988, the DOE awarded a contract to a commercial carrier for the first 5 years of truck transport of TRU waste to the WIPP. This detailed contract (SEIS Appendix D) includes the design specifications for the tractor-trailer rigs; requirements for driver qualifications and training; equipment maintenance; maintenance facilities and records; and procedures for TRU waste transportation, mechanical failures, and emergencies. The commercial carrier is responsible for providing a contract manager, a tractor-trailer fleet, and qualified drivers that are dedicated solely to this TRU waste transportation contract. Prototypes of the tractor-trailer rig and TRUPACT-II packagings with simulated, non-radioactive waste cargo are now being road tested. The requirements of the trucking contract in all these areas are highly specific and demanding.

An important feature of the truck transport mode is the Transportation Tracking and Communications System (TRANSCOM) that will be used to ensure the safe and efficient transport of TRU wastes to the WIPP. The TRANSCOM (Figure 3.4) will combine navigation, satellite communication, and computer network technologies to monitor the movement of TRU waste shipments to the WIPP. Each tractor-trailer rig will be equipped with a two-way communications system in the tractor cab and Loran satellite and antenna mounted on the trailer. Each tractor-trailer rig will automatically send a signal every 15 minutes to update its geographical location and status (moving or stopped) and to verify that the established transportation route is being followed. The system will provide the nearest emergency points of contact (e.g., police, highway patrol, and emergency operation centers) should an emergency or mechanical failure occur. A detailed description of TRANSCOM is provided in SEIS Appendix D.

The DOE is committed to using the TRANSCOM 24 hours per day to enhance the safe and efficient transport of TRU waste to the WIPP, and the communications center has developed a computer network and data base that provides easy access to shipment information. The system is designed to provide both DOE users (e.g., storage and generator sites) and approved non-DOE users (e.g., involved state and tribal governments) with an interface with the communications center via personal computers. The system's computer software has been developed, and a commercial satellite telecommunication system has been selected. Tests have been conducted using tractor trailer combinations and TRUPACT containers (without TRU waste) to verify the effectiveness of the TRANSCOM system.

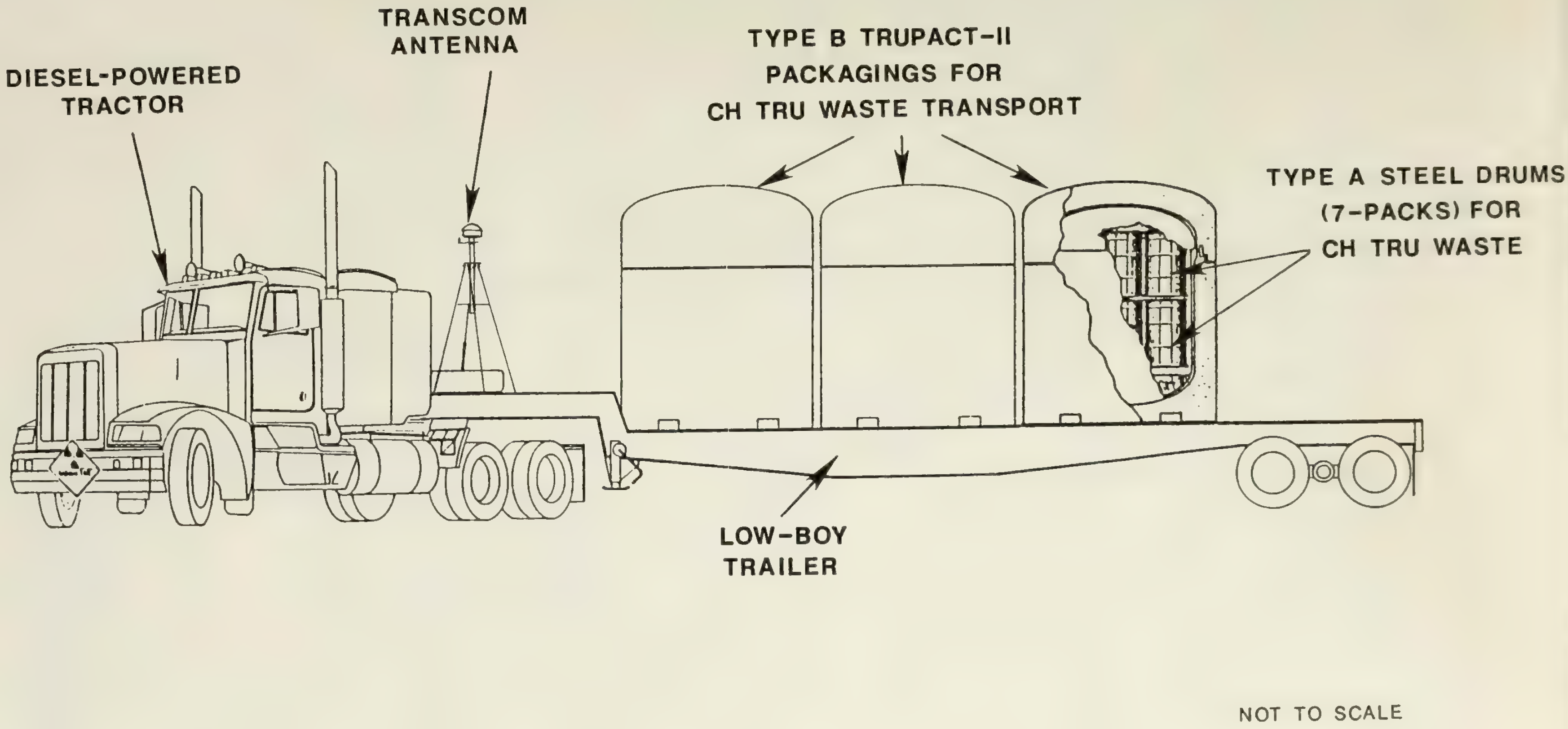


FIGURE 3.3

TYPICAL TRACTOR-TRAILER COMBINATION FOR TRU WASTE TRANSPORT

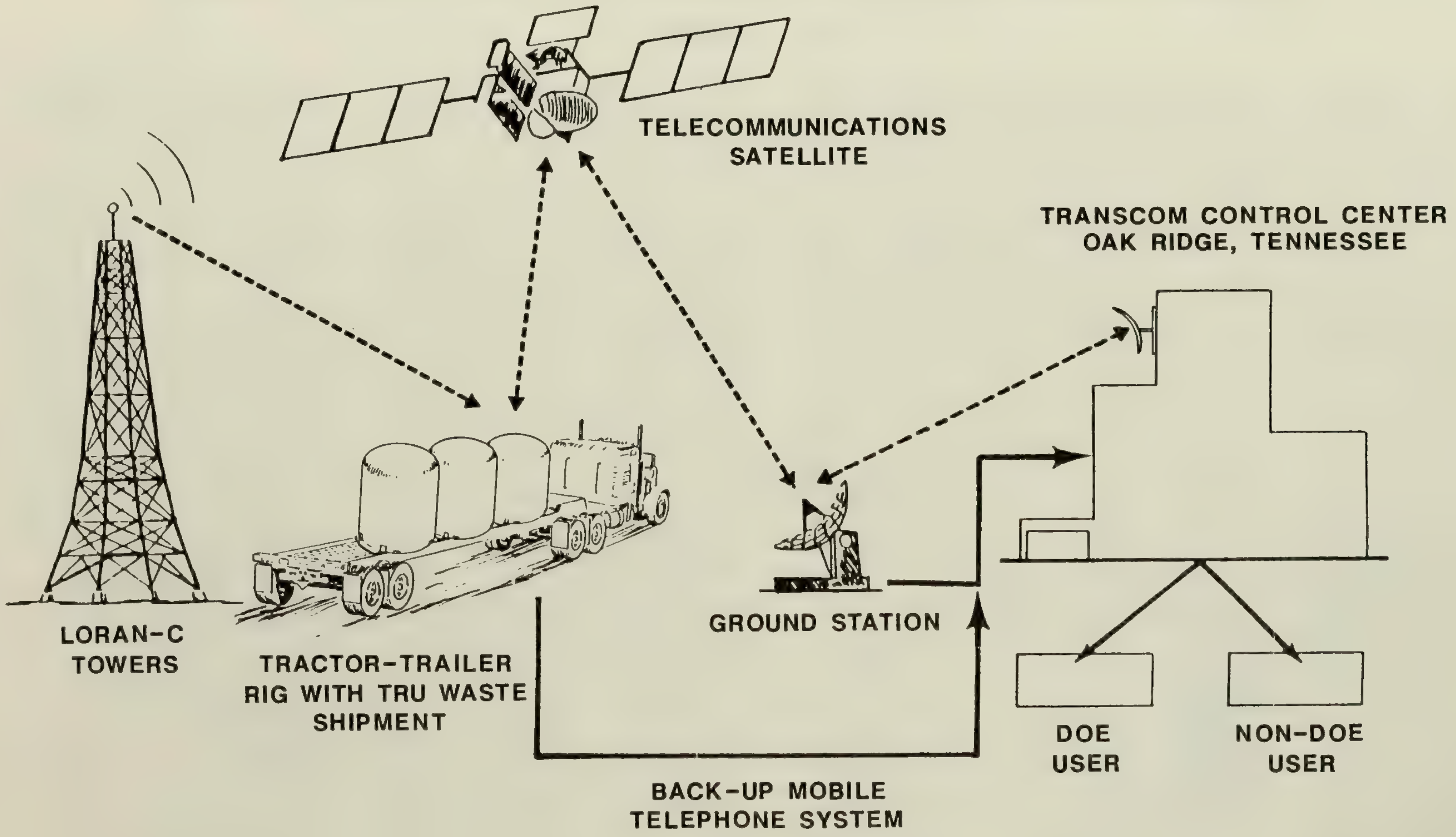


FIGURE 3.4
SCHEMATIC OF THE TRANSCOM

As discussed above, the DOE is now developing a Type B packaging (NUPAC 72B) for the transportation of RH TRU waste to the WIPP. The trailers for the NUPAC 72B cask are in the design stage. It is expected that the cask will be transported by the same tractor and monitored in the same way as the TRUPACT-II shipments. Also, as previously discussed, the process for obtaining NRC certification of Type B packagings for rail transport of CH and RH TRU waste has not been initiated. Therefore, details on the rail transport mode (e.g., use of the TRANSCOM with rail transport) are not available at this time. It should be noted that commercial rail transport would cost more than truck transport and the DOE would not be able to strictly control the waste shipments. Similarly, commercial rail transport presents the potential for TRU waste shipments to sit idle on sidings in railroad yards in urban areas for extended periods of time.

Transportation Routes. The FEIS (Subsections 6.4 and 6.7) analyzed the transportation of TRU waste to the WIPP from only two sites, the Rocky Flats Plant in Colorado and the Idaho National Engineering Laboratory in Idaho. To provide a more comprehensive analysis, this SEIS analyzes the environmental consequences of waste transportation from ten storage and generator facilities, although shipment from only four such facilities is currently proposed. The analysis considers the two transportation modes previously described (truck and maximum rail transport), and the typical transportation routes between the storage and generator facilities and the WIPP for these two modes.

The Federal regulations pertaining to transportation routes for TRU waste shipments are set forth by the DOT in 49 CFR Parts 171, 174, and 177. For truck transportation routes, 49 CFR Part 177.825 requires that the interstate highway system be used to the maximum extent possible for highway route control of radioactive materials (49 CFR Part 173.403). However, 49 CFR Part 171.8 provides that appropriate state agencies can, under certain circumstances, require other routes if analyses demonstrate that the other routes will result in less risk to the general public. The regulations for rail transportation in 49 CFR Part 174 address only the special handling requirements for radioactive materials and do not provide any requirements for the routing of rail shipments.

The proposed routes for truck transport of TRU waste from the ten defense program facilities to the WIPP are shown on Figure 3.5. These routes use the interstate highway system to the maximum extent possible; however, there are several exceptions that include the use of U.S. Highway 95 to access the Nevada Test Site and U.S. Highway 285 to access the WIPP site. When possible, TRU waste shipments will use beltways around urban areas. Detailed route descriptions from each defense facility to the WIPP are provided in SEIS Appendix D.

Each of the 23 corridor states was contacted to provide a qualitative assessment of road segments of concern along the proposed route in their state. In general, reported segments of concern are related to weather conditions, rush-hour traffic in larger urban areas, or miscellaneous road features (e.g., dangerous curve). Table D.2.1 (SEIS Appendix D) provides a summary of the reported segments of concern. The DOE will provide the carrier with this information. Because many of the concerns are related to winter driving conditions in the mountains, parking areas will be designated in concert with the corridor state, as appropriate.

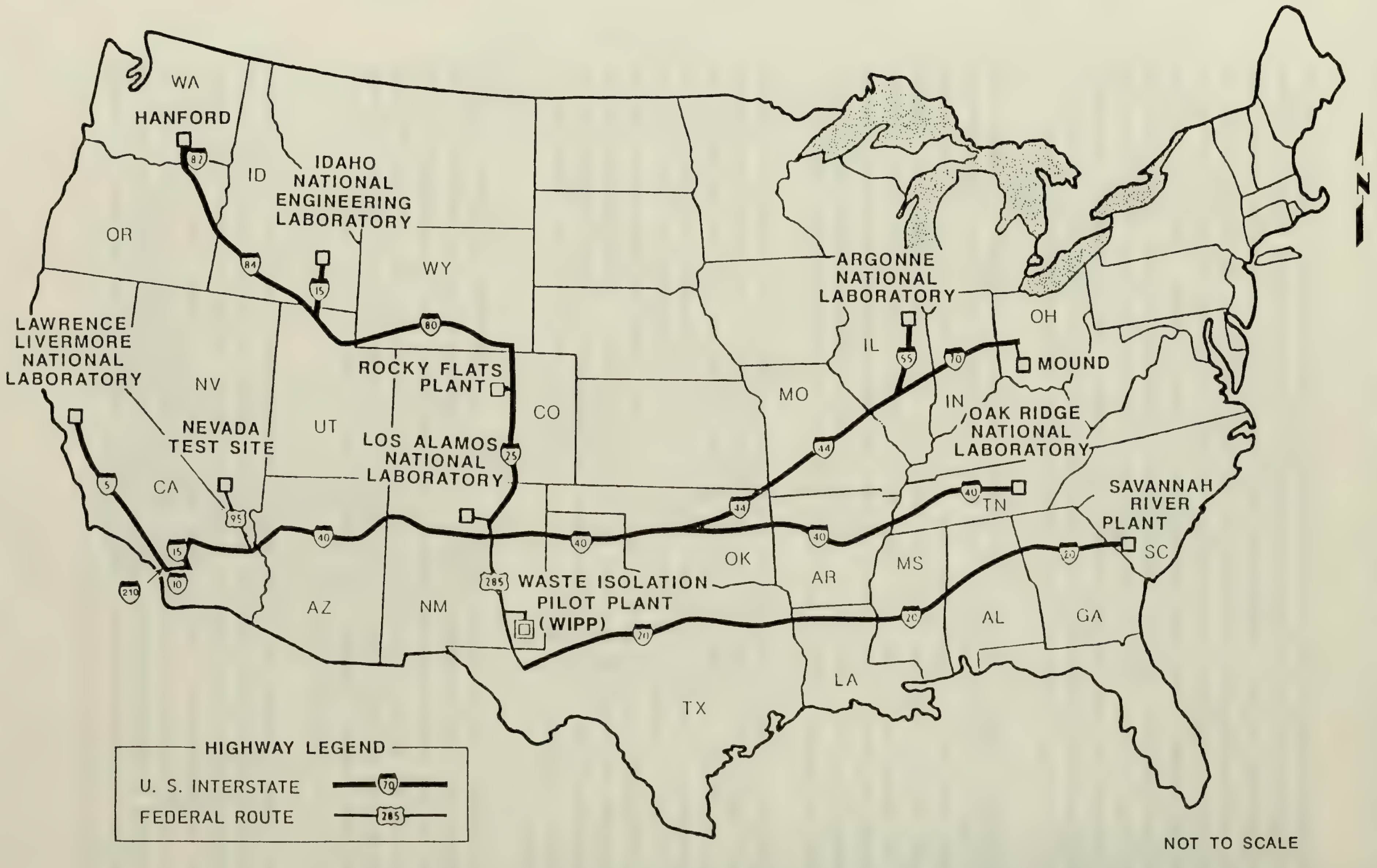


FIGURE 3.5
PROPOSED TRU WASTE TRUCK TRANSPORTATION ROUTES

The highway mileages for the DOT-approved truck transportation routes are provided in Table 3.6. As noted in the table, the range of highway mileage accounts for alternate routes or detours that could be required due to traffic accidents, highway maintenance, or adverse weather conditions. The average highway mileage is a conservative transportation distance that includes some alternate routes and detours; this mileage was used in this SEIS to analyze the environmental consequences of TRU waste transportation to the WIPP.

Figure 3.6 shows typical rail transportation routes to the WIPP from the eight generator facilities that presently have railroad access. As previously noted, these routes are not required to be approved by the DOT for the shipment of TRU waste. The mileages for the typical rail transportation routes are provided in Table 3.7. As with the highway mileages for the DOT-approved truck transportation routes, these mileages account for alternate routes and detours that may be required during waste shipment.

Six mainline railroad companies have lines that would directly access eight of the ten defense program facilities: 1) the Atchison, Topeka and Santa Fe, 2) the Union Pacific (also owns Missouri Pacific), 3) Mid-South, 4) CSX Transport, 5) Southern, and 6) Denver Rio Grande. Only the Argonne National Laboratory is on a direct line to the WIPP. Shipments from the other defense program facilities would require between one and five transfers.

3.1.1.4 Implementation of a Test Phase. The initial step of the Proposed Action is to conduct a Test Phase of approximately 5 years. The DOE is currently developing a detailed plan for the Test Phase.

During the Test Phase, the DOE proposes to operate the WIPP with limited amounts of waste. For this SEIS, the DOE assumes that the maximum amount of TRU waste that would be used during the Test Phase is 10 percent of the TRU waste by volume that could ultimately be permanently emplaced at the WIPP. The actual amount of waste proposed for the Test Phase may be less. Subsets of the Proposed Action include conducting the Test Phase with bin- and/or room-scale tests without the integrated operations demonstration tests and the conduct of these tests with lesser volumes of waste than assumed in the SEIS for the purpose of bounding the impacts. The impacts of these subsets would be bounded by the analysis of the Proposed Action in this SEIS. Any waste brought to the WIPP during the Test Phase would remain fully retrievable during this Test Phase period and for a reasonable period thereafter if a decision is made to proceed to the Disposal Phase.

The Test Phase has two distinct parts: 1) the Integrated Operations Demonstration and 2) the Performance Assessment.

Integrated Operations Demonstration. The Integrated Operations Demonstration is proposed to show the ability of the waste management system to safely and efficiently certify, package, transport, and emplace waste at the WIPP. Testing and monitoring would be done on generating and storage facility operations, the transportation system, and the WIPP site operations. These testing and monitoring activities are intended to substantiate the safety and efficiency of WIPP operations and associated waste management systems under realistic conditions.

TABLE 3.6 Highway mileage for DOT-approved truck transportation routes[a]

Storage or generator site	Average highway mileage	Range of highway mileage
Idaho National Engineering Laboratory, Idaho	1521	1338-1771
Rocky Flats Plant, Colorado	874	749-1072
Hanford Reservation, Washington	1913	1745-2177
Savannah River Plant, South Carolina	1585	1447-1663
Los Alamos National Laboratory, New Mexico	343	343
Oak Ridge National Laboratory, Tennessee	1350	1303-1393
Nevada Test Site, Nevada	1286	1024-1456
Argonne National Laboratory-East, Illinois	1387	1329-1419
Lawrence Livermore National Laboratory, California	1458	1370-1527
Mound Laboratory, Ohio	1472	1428-1511

[a] The range of highway mileage accounts for alternate routes and detours that may be required due to traffic accidents, route maintenance, or adverse weather conditions. The average highway mileage includes some alternate routes and detours; this distance was used to analyze the environmental consequences of TRU waste transportation to the WIPP (DOE, 1986).

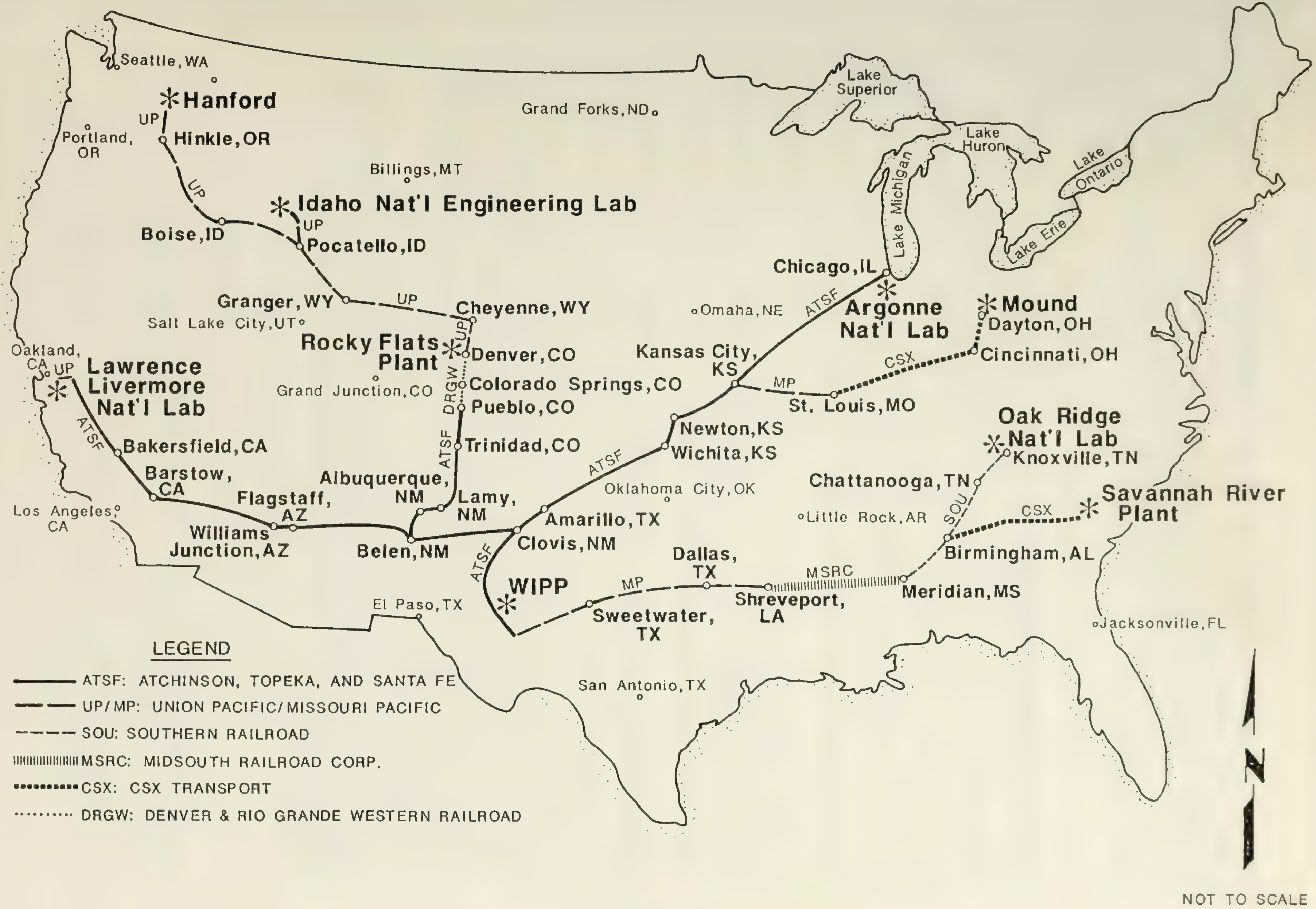


FIGURE 3.6

PROPOSED MAINLINE RAILROAD ROUTES FOR TRUWASTE TRANSPORTATION TO THE WIPP

TABLE 3.7 Railroad mileages for rail transportation routes[a]

Storage or generator site	Average railroad mileage	Range of railroad mileage
Idaho National Engineering Laboratory, Idaho	1761	1466-2054
Rocky Flats Plant, Colorado	1098	748-1572
Hanford Reservation, Washington	2296	1992-2579
Savannah River Plant, South Carolina	1915	1786-2074
Los Alamos National Laboratory, New Mexico	343	343[b]
Oak Ridge National Laboratory, Tennessee	1630	1552-1676
Nevada Test Site, Nevada	1286	1024-1456[b]
Argonne National Laboratory-East, Illinois	1469	1279-1658
Lawrence Livermore National Laboratory, California	1873	1657-2242
Mound Laboratory, Ohio	1677	1625-1726

[a] The range of railroad mileage accounts for alternate routes and detours that may be required due to accidents, route maintenance, or adverse weather conditions. The average railroad mileage includes some alternate routes and detours; this distance was used to analyze the environmental consequences of TRU waste transportation to the WIPP (DOE, 1986).

[b] At the present time, there is no railroad access to Los Alamos National Laboratory in New Mexico and the Nevada Test Site in Nevada. Only the environmental consequences of truck transportation of TRU waste from these sites to the WIPP were analyzed in this SEIS.

During the Integrated Operations Demonstration, TRU waste would be retrievably emplaced in the repository. The WIPP operating staff would conduct these handling operations in accordance with the requirements of RCRA and other applicable regulations and Subpart A of 40 CFR 191. The Integrated Operations Demonstration is the culmination of a thorough approach to the construction and testing of the WIPP prior to waste receipt for permanent disposal.

The three primary elements of the program include:

1) Operation of the WIPP with TRU wastes at rates of emplacement up to rates that represent full-scale operations of the repository. This would evaluate overall safety and productivity at the WIPP, ensure that operations are consistent with environmental considerations, and demonstrate compliance with regulations and DOE Orders. The interaction and integration of surface, hoist, and underground operations would be evaluated while handling radioactive wastes. Further, this evaluation would include the concurrent handling of CH and RH waste at operational rates. These waste emplacement operations would be performed concurrently with mining operations.

   Waste management activities to be demonstrated include waste transporter receipt, waste unloading, and waste transfer to the storage locations in the underground disposal area. Activities would be documented and analyzed to develop a safety, productivity, schedule, and operability data base.

2) Waste management activities at DOE waste generating/storage facilities, including waste certification, and waste packaging and loading for shipment to the WIPP. Prior to shipment of wastes to the WIPP, management of waste is the responsibility of the individual waste generating or storage facilities. However, specific site operations pertaining to waste transportation and certification of waste to WIPP WAC would be included as part of the program so that overall safety and efficiency could be evaluated.

3) Transportation of TRU waste to the WIPP, including shipping container and trailer operations, shipment tracking using the TRANSCOM satellite tracking system, and regulatory compliance monitoring. To ensure that personnel at the WIPP and defense program facilities, and the contract carrier are prepared to make shipments safely and efficiently, several trial runs would be made. The purpose of these runs would be to:

   - Demonstrate preparation for shipment of TRUPACT-II

   - Meet dispatching requirements

   - Further train operators at the facilities in the loading and unloading of TRUPACT-IIs

   - Communicate with drivers and monitor shipment locations using TRANSCOM

- Establish base transit times from facilities to the WIPP.

Performance Assessment. The second major proposed subpart of the Test Phase is the performance assessment. Since publication of the FEIS in 1980, the EPA promulgated standards in 40 CFR Part 191, Subpart B, for the permanent disposal of TRU waste. These standards were vacated and remanded to the EPA by a Federal Circuit Court of Appeals for reconsideration and repromulgation, and are not expected to be repromulgated in final form until approximately 1991 or 1992. In the interim, the DOE has agreed with the State of New Mexico to proceed with its long-term performance assessment planning as if the standards were still in effect. The following subsections describe the performance assessment activity as now proposed.

As noted in SEIS Subsection 1.3., the information presented in the SEIS is not intended to be a performance assessment within the meaning of the standard or to demonstrate compliance with the remanded 40 CFR Part 191, Subpart B. Rather, the SEIS describes proposed Test Phase activities that will enable the DOE in the future to ascertain, based on a performance assessment, whether the repository can meet the standards.

Subpart B applies to the repository after decommissioning and limits cumulative releases of radioactive materials to the "accessible" environment over 10,000 years. This Subpart also limits the annual radiation doses to members of the public and radioactive contamination of groundwater for a period of 1000 years after disposal of the waste. In essence, the primary objective of Subpart B is to ensure that the disposal system will isolate the waste from the accessible environment by limiting long-term releases and the consequent risks to human individuals. Subpart B also establishes a number of assurance requirements to provide confidence in long-term compliance with the containment requirements.

Performance assessment, as defined in 40 CFR Part 191, requires "an analysis that: 1) identifies the processes and events that might affect the disposal system; 2) examines the effects of these processes and events on the performance of the disposal system; and 3) estimates the cumulative releases of radionuclides, considering the associated uncertainties, caused by all significant processes and events." For the WIPP project, and consistent with this definition, the final performance assessment method will be a complex process involving seven major components: 1) data collection and model development, 2) scenario development and screening, 3) preliminary consequence analysis, 4) sensitivity and uncertainty analysis, 5) final consequence analysis and comparison with the standard, 6) analysis of undisturbed performance, and 7) documentation.

Data collection regarding the geologic and hydrologic character of the area surrounding the WIPP has been under way for 14 years as part of site characterization and repository design activities (see, for example, Lappin, 1988). Numerical models have been developed that will be incorporated into the performance assessment computational method. Characterization of the disposal system and the surrounding area, and the development of models would continue during the Test Phase.

Scenarios that describe the possible events that could affect the performance of the repository during the long term are being developed. In accordance with Appendix B of 40 CFR Part 191, scenarios can be omitted from the performance assessment if their probability of occurrence is less than 1 chance in 10,000 of occurring over 10,000 years. Some of the events or processes estimated to have a greater probability may be deleted if there is a reasonable expectation that the remaining probability distribution would not be significantly changed by their omission. Events retained for the WIPP scenario development include the effects of a pressurized brine occurrence beneath the WIPP, climatic change, groundwater flow, drilling into the repository, and others. It is expected that the 110 possible scenarios developed to date would be reduced to approximately 10 to 15, which would ultimately be analyzed in the performance assessment.

Preliminary consequence analysis of the scenarios would be used to assemble and test the entire set of codes, models, and techniques that are necessary to project repository performance for comparison with the 40 CFR Part 191 standards. Any deficiencies identified in the methodology would be corrected before the final consequence analysis is performed.

Sensitivity analysis for each scenario would be performed during the preliminary consequence analysis. Sensitivity analysis is a means of determining the relative importance of the parameters used in a calculation. Detailed sensitivity analysis of parameters such as the geologic, hydrologic, and transport components of the performance assessment system would be undertaken, as well as a sensitivity analysis of the repository and shaft components.

Uncertainty analysis determines the uncertainty in the performance assessment calculation resulting from uncertainties in models and the data. Scenario probabilities would be addressed through external peer review. Model uncertainty would be addressed through verification, validations, calibration programs, and quality assurance. Monte Carlo sampling would be used to address uncertainty in input data.

Final consequence analysis would be performed for each scenario that is determined to be significant during the scenario screening process. This would be performed using the performance assessment methodology described for preliminary consequence analysis and modified as necessary to correct for deficiencies found during the earlier analysis. The result would be compared to the Standards in 40 CFR Part 191, Subpart B.

For analysis of undisturbed performance, if any release of radionuclides is projected for the first 1,000 years, then the annual doses would be calculated. Calculations would also be performed to determine the quantities of radionuclides that could be released to the accessible environment during the first 10,000 years after decommissioning of the WIPP and the probabilities of such releases.

The proposed Test Phase includes bin-scale tests and room-scale tests to provide data for the performance assessment calculation process.

- Bin-Scale Tests. The bin-scale tests are being designed to provide information concerning gas production, gas composition, and gas depletion rates as well as radiochemical source term data from actual CH TRU waste. CH TRU waste would be mixed with backfill, brine, and salt to simulate conditions to which the waste would be exposed within the repository. The waste used would be representative of the general TRU waste inventory. The source of the waste would be newly-generated waste with high-organic, low-organic, and prepared sludge components. Old waste with high-organic content would also be used.

The waste would be tested under a variety of conditions, including aerobic (containing oxygen) and anaerobic (lacking oxygen) conditions that simulate operational and post-operational phases. The waste would be brought into contact with a variety of types and qualities of brines. Experiments would also be conducted to provide information about waste interactions with salt, container metals, backfill, and materials that absorb gases. Finally, experiments would provide information about the production of gas by wastes in various modes (including saturation, compaction, bacterial action, and degradation product contamination).

The WIPP bin-scale tests involve testing of specially-packaged and prepared TRU waste in specially designed, transportable sealed bins. The bin would be a metal box with sampling ports and instrumentation. Each bin would be able to accommodate the equivalent of about six drums of CH TRU waste. Each bin would be prepared and filled at the generator facility with TRU waste mixed with backfill and/or salt. Brine would only be added at the WIPP site. The test bin would fit within a standard TRU-waste box (SWB) for transportation to the WIPP.

All test bins would have a carefully sealed internal environment that would be accessed by gas sampling ports, pressure gauges, and control systems, as well as temperature monitors. Some would also have ports for brine injection, liquid sampling, and solids sampling.

- Room-Scale Tests. Data would be obtained from the room-scale tests on production, depletion, and composition of gases resulting from in situ degradation of TRU wastes. These tests would provide additional confidence in the performance assessment analyses described earlier. Because of the potential uncertainties inherent in extrapolating laboratory or even bin-scale results to the full-scale repository, room-scale tests would be performed within the WIPP repository to validate gas generation models and predicted impacts for realistic waste inventory emplacements. In addition to eliminating the uncertainties associated with scaling results from smaller-scale experiments, room-scale tests would incorporate the impacts of the actual repository environment on the degradation behavior of the wastes. The room-scale tests would also experimentally address the predicted effect of emplacement of engineered backfills on the evolved gases, and would examine the gas generation potential of supercompacted waste.

  The TRU waste for the room-scale tests would include wastes both as received and specially prepared at generator sites, before shipment to the WIPP. Specially prepared CH TRU wastes would include added backfill materials, gas getter materials, and/or brine. The waste types would be representative of wastes proposed to be permanently emplaced in the WIPP,

> including high-organic, newly-generated waste; low-organic, newly-generated waste; processed sludges; high-organic old wastes; and others.
>
> The room-scale tests would be located within four sealed, atmosphere-controlled test rooms or "alcoves." Wastes would be located within three alcoves and one alcove would be an empty gas reference-baseline room. Each alcove is designed to be 13 ft in height, by 33 ft wide, by 150 ft in length. A 10-ft by 13-ft entryway would be fitted with an inflatable packer-seal plug to seal the room, and, thus, simulate anoxic repository conditions. Both bin and room-scale tests are proposed to obtain gas generation and source term data.

At the conclusion of the Test Phase, the DOE would decide whether, based upon a performance assessment, the WIPP would comply with 40 CFR Part 191, Subpart B. If there is a determination of compliance, the WIPP would move into the Disposal Phase. If there is a determination of noncompliance with 40 CFR Part 191 of Subpart B, a number of options would be considered (e.g., waste treatment) and the required NEPA documentation will be prepared.

3.2 ALTERNATIVES

The Council on Environmental Quality (CEQ) regulations implementing the procedural provisions of the National Environmental Policy Act require an EIS to "rigorously explore and objectively evaluate all reasonable alternatives, and for alternatives which were eliminated from detailed study, to briefly discuss the reasons for their having been eliminated" (40 CFR 1502.14). These regulations also require the inclusion of the No Action alternative.

As discussed in SEIS Subsection 3.1, the Proposed Action is an extension of the decision rendered in the ROD (DOE, 1981) along with proposed modifications since that time. The Proposed Action would be initiated in late 1989 with the emplacement of selected TRU wastes underground; this would constitute the beginning of the Test Phase. The fundamental issue at this time is whether to initiate the proposed Test Phase or to conduct tests (part of the Test Phase) aboveground and not emplace waste in the WIPP until compliance with the EPA standards in 40 CFR Part 191, Subpart B, has been determined on the basis of a performance assessment. The DOE has determined that the use of simulated, nonradioactive waste in support of the performance assessment and proceeding with performance assessment with no tests involving wastes are unreasonable alternatives, as explained in SEIS Subsection 3.3.

3.2.1 No Action Alternative

The No Action alternative in this SEIS is similar to the one discussed in the FEIS with the additional implications of No Action for the Savannah River Plant and Hanford Reservation facilities. TRU wastes would continue to be generated and stored in temporary facilities. The WIPP would be decommissioned and potentially put to other uses. The potential long-term hazards to public health and the environment would remain as a consequence of long-term use of facilities that were designed only for interim storage.

The No Action alternative would result in the potential for long-term degradation of the environment and potential public health consequences at TRU waste generator and storage facilities and may have adverse impacts on nuclear weapons programs and maintenance.

3.2.2 Alternative Action

This SEIS also evaluates an alternative to the Proposed Action that would allow no emplacement of TRU waste in the WIPP underground until a determination has been made of compliance with the EPA standards in 40 CFR Part 191, Subpart B. Of those components of the Test Phase that are proposed for the WIPP underground, only the bin-scale tests portion could be reasonably conducted at a location other than the WIPP underground.

Thus, this alternative is essentially the same as the Proposed Action except for changes in the Test Phase. The bin-scale tests would be conducted at a DOE location other than the WIPP underground. These tests would need to be conducted in a specially engineered aboveground facility that would be constructed for this purpose. This alternative calls for no radioactive waste emplacement into the WIPP underground until the bin-scale tests performed at an alternative location have been completed, and the results used in a performance assessment for determining compliance with 40 CFR Part 191, Subpart B.

Since the room-scale tests could not be practically or usefully performed elsewhere than the WIPP underground, the results of the room-scale tests would not be available to allow confident extrapolation of laboratory and bin-scale results to a full-scale representative repository loading. Thus the uncertainty in the performance assessment would be greater than under the Proposed Action. If the uncertainty in the performance assessment should be unacceptable, the DOE would evaluate further courses of action. One option might be to conduct room-scale tests similar to those described in the Proposed Action. In that case, such room-scale tests would be delayed for up to 5 years relative to the Proposed Action (2 years for bin-scale facility construction and 3 years for bin-scale testing and performance assessment evaluation).

In addition, the Integrated Operations Demonstration portion of the WIPP Test Phase would not be conducted prior to the completion of the compliance determination. This is in keeping with the concept of zero waste into the WIPP during this period. This portion of the Test Phase may have to be completed prior to the permanent Disposal Phase. If so, the permanent Disposal Phase could be delayed relative to the Proposed Action.

This alternative would delay the movement to the WIPP of newly-generated TRU waste from the Rocky Flats Plant and stored waste from the Idaho National Engineering Laboratory. This newly-generated waste from the Rocky Flats Plant would either have to be continually shipped to the Idaho National Engineering Laboratory or would have to be shipped to another location identified for interim storage. All other actions as described in the Proposed Action would remain the same under this alternative, although several activities could be delayed as described.

The objective of the bin-scale tests under this alternative is identical with that described under the Proposed Action. Bin-scale tests for this alternative could be accomplished at any one of several DOE site locations and would require the construction of a specialized facility to perform the tests. Alternative locations that could be used include the Idaho National Engineering Laboratory, the Rocky Flats Plant, the Nevada Test Site, and the WIPP aboveground. For purposes of analyzing the impacts of this alternative, which would generally be representative of impacts associated with bin-scale tests aboveground for any of these alternative locations, the Idaho National Engineering Laboratory was chosen as a representative site. It is not the DOE's intent to propose the Idaho National Engineering Laboratory as the site for bin-scale tests, but simply to use it to illustrate representative levels of impact. As will be shown in the impact section for this alternative (SEIS Subsection 5.3), the impacts associated with facility construction and the conduct of bin-scale tests at the Idaho National Engineering Laboratory would be largely the same as for the construction and conduct of bin-scale tests at other locations. This is because of the localized and temporary nature of construction impacts and the small scale of the TRU waste tests. Impacts associated with transportation could vary, depending on the site chosen.

Under this alternative, a controlled-environment facility would be built aboveground. The actual building would be constructed to be tornado and seismic resistant. The building would be required to have a minimum 12-ft interior clear height and would have a floor space of 60 ft by 110 ft. An airlock entryway, bin unloading and preparation area, bin storage area, office, lab and forklift holding area would be included in the interior space. The instrumented facility would have fire detection and suppression systems, and a heating, ventilation and air conditioning (HVAC) system with double high-efficiency particulate air (HEPA) filters. Test equipment would include radiation monitoring equipment, chemistry and gas analysis equipment, a data acquisition system, and others. A 5-ton-capacity overhead crane and a 3-ton forklift truck would be required for handling.

The estimated total cost for design, site preparation, and construction would be approximately $3,473,000 in 1989 dollars. It should be noted that costs would be duplicated because a test facility is already in place at the WIPP. The time required for RCRA permitting and the design and construction of such a facility is estimated to be approximately 2 years. In effect, the start of bin-scale testing would be delayed for at least a 2-year period pending the securing of permits, completion of engineering designs, and construction.

3.3 ALTERNATIVES NOT CONSIDERED IN DETAIL

The DOE also considered the possibility of performing experiments in support of the performance assessment with simulated, nonradioactive waste. While this alternative holds the potential to avoid the effects associated with the use of radioactive waste during the Test Phase, it was determined to be unreasonable.

For the confident evaluation of the effect of gases on the long-term behavior of the repository, it is necessary to use actual TRU (radioactive) waste such that relevant and sufficient data can be obtained. Several different types of data regarding the behavior of TRU wastes are required. These include information about gas generation, gas specification, and gas depletion rates as a function of time and of various waste conditions. The impacts of radiolytic, bacterial, and chemical corrosion degradation mechanisms can only be adequately analyzed in tests that use actual radioactive TRU waste. Finally, the synergisms, or complex interactions, between various ongoing in situ processes can only be effectively analyzed when actual TRU wastes are used.

A variation of this alternative would be to proceed with the performance assessment with no tests using waste in the WIPP and no new construction for aboveground tests. This alternative is unreasonable for the reasons given above with respect to using simulated waste. In both cases, the DOE would not have sufficient data for conducting a performance assessment that would provide a basis for determining compliance with 40 CFR Part 191, Subpart B.

REFERENCES FOR SECTION 3

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3	3-33	References	Second citation document number, DOE/WIPP 87-013, should read DOE/WIPP 88-xxx.

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Rockwell International, 1988. "Hazardous Constituents of Rocky Flats Transuranic Waste," internal letter for distribution from J. K. Paynter, May 24, 1988, WCP02-31, Golden, Colorado.

WEC (Westinghouse Electric Corporation), 1989. Radioactive Mixed Waste Compliance Manual, Appendix 6.4.1, WP-02-07, Rev. 0, WIPP, Carlsbad, New Mexico.

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4.0 DESCRIPTION OF THE EXISTING ENVIRONMENT

This section describes the existing environment at the WIPP site and summarizes and updates the information provided in Section 7 and the referenced appendixes of the FEIS. Information that describes the existing environment at the Idaho National Engineering Laboratory, the Rocky Flats Plant, the Hanford Reservation, and the Savannah River Plant is available in DOE (1988a), DOE (1980), DOE (1987), and DOE (1988b), respectively.

4.1 EXISTING ENVIRONMENT AT THE WIPP SITE

The monitoring of construction activities, the continuation of studies initiated for the FEIS, and the initiation of studies since the FEIS have generated new information concerning the WIPP site. This section summarizes and updates FEIS Section 7.1; it also includes the results of the environmental monitoring programs and raptor (bird of prey) studies initiated since the FEIS.

4.1.1 Biological Environment

The WIPP site is in an area characterized by stabilized sand dunes. The vegetation is dominated by shinnery oak (*Quercus havardii*), mesquite (*Prosopis glandulosa*), sand sage (*Artemisia filifolia*), dune yucca (*Yucca campestris*), smallhead snakeweed (*Gutierrezia microcephala*), three-awn (*Aristida* spp.), and numerous species of forbs and perennial grasses. The dominant shrubs are deep-rooted species with extensive root systems. The shrubs not only stabilize the dune sand but serve as food, shelter, and nesting sites for many species of wildlife inhabiting the area.

The wildlife is characterized by numerous species of mammals, birds, reptiles, and amphibians. The most conspicuous mammals at the site are the black-tailed jack rabbit (*Lepus californicus*) and the desert cottontail (*Sylvilagus auduboni*). Common small mammals found since 1984 include Ord's kangaroo rat (*Dipodomys ordii*), the plains pocket mouse (*Perognathus flavescens*), and the northern grasshopper mouse (*Onychomys leucogaster*). Big-game species, such as the mule deer (*Odocoileus hemionus*) and the pronghorn antelope (*Antilocapra americana*), and carnivores, such as the coyote (*Canis latrans*), are present in small numbers.

Numerous birds inhabit the area either as transients or year-long residents. Loggerhead shrikes (*Lanius ludovicianus*), pyrrhuloxias (*Cardinalis sinuata*), and black-throated sparrows (*Amphispiza bilineata*) are examples of common residents. Migrating or breeding waterfowl species do not frequently occur in the area. Some raptors [e.g., Harris hawks (*Parabuteo unicinctus*)] are residents. The density of large-avian-predator nests has been documented as among the highest recorded in the scientific literature. Aquatic habitats near the WIPP site include stock-watering ponds and tanks. These may be frequented by yellow mud turtles (*Kinosternon flarescens*), tiger salamanders (*Ambystonon tigrinum*), and occasional frogs and toads. Fish are sometimes stocked in the ponds and tanks.

The New Mexico Department of Game and Fish (NMDG&F) (Hubbard et al., 1985, and updated by NMDG&F Regulation No. 657) lists 2 mammals, 13 birds, 6 reptiles, 1 amphibian, 8 fish, and 3 mollusks in one of two endangerment categories. The Handbook of Rare and Endemic Plants of New Mexico (UNM, 1983), which lists the plants classified as threatened, endangered, or sensitive in New Mexico, includes 20 species, representing 14 families, that are found in Eddy County and could occur at or near the WIPP site.

The DOE consulted with the U.S. Fish and Wildlife Service (USFWS) in 1979 to determine the presence of threatened and endangered species at the WIPP site (see Appendix I of the FEIS). At that time, the USFWS listed the Lee pincushion cactus (*Coryphantha sneedi* var. *leei*), the black-footed ferret (*Mustela nigripes*), the peregrine falcon (*Falco peregrinus anatum*), the bald eagle (*Haliaeetus leucocephalus*), and the Pecos gambusia (*Notropis simus pecosensis*) as threatened or endangered and as occurring or having the potential to occur on lands within or outlying the WIPP site. The USFWS now lists an additional six species of plants and vertebrates as being threatened or endangered and as occurring or having the potential to occur within the geographic region of the WIPP site. The new species not listed in the FEIS are the Aplomado falcon (*Falco femoralis septemornalis*), endangered; the Pecos bluntnose shiner (*Notropis simus pecosensis*), threatened; the gypsum wild buckwheat (*Eriogonum gypsophilum*), threatened; Lloyd's hedgehog cactus (*Echinocereus lloydii*), endangered; the McKittrich pennyroyal (*Hedeoma apiculatum*), threatened; and the Sneed pincushion cactus (*Coryphantha sneedii* var. *sneedii*), endangered. The DOE believes that the actions described in the SEIS will have no impact on any threatened or endangered species because these activities do not involve any ground disturbance that was not already evaluated in the FEIS.

In addition, there is no critical habitat for terrestrial species identified as endangered by either the USFWS or the NMDG&F at the site area. The DOE will undertake additional consultation with the USFWS as an update to consultation undertaken in 1980 required under Section 7 of the Endangered Species Act.

For a detailed description of the biological environment of the area, the reader is referred to Subsection 7.1 and Subsection H-5 of Appendix H in the FEIS, the literature cited therein, and the WIPP Environmental Monitoring Program described in SEIS Subsection 2.9.2 (Reith and Daer, 1985; Fischer et al., 1985, 1987, 1988).

4.1.2 Socioeconomic Environment

The socioeconomic environment of the area surrounding the WIPP site is described in Subsection 7.2 of the FEIS. Since the publication of the FEIS, declines in the oil, gas, and mining industries have depressed the economy of the area.

There are 26 permanent residents within 10 miles of the WIPP site. Most of the population within 50 miles of the WIPP site is concentrated in and around the communities of Carlsbad, Hobbs, Eunice, Loving, Jal, and Artesia, New Mexico. The nearest community is the town of Loving, New Mexico, 18 miles west-southwest of the site center. The population of Loving decreased from an estimated 1,600 in 1980 to 1,450 in 1986, the year of the latest census. The nearest population center is the city of Carlsbad, New Mexico, 26 miles west of the site. The population of Carlsbad has increased from an estimated 28,600 in 1980 to an estimated 29,500 in 1988. The transient population within 10 miles of the site is associated with ranching, maintenance of oil and gas wells, and potash mining. There are three ranches within 5 miles of the site; these are the Mills, Smith, and Mobley ranches. Only the Mills Ranch, owned by J. C. Mills, has a ranch house located within five miles of the site. Three mining operations within 10 miles of the WIPP site employ approximately 360 persons per shift, with 450 persons present during shift changes.

4.1.3 Transportation

The WIPP site can be reached by rail or highway. The DOE has constructed a rail spur to the site from the Atchison, Topeka and Santa Fe Railroad (ATSF) six miles west of the site (see Figure 2.1). The site can be reached from the north and south access roads constructed for the WIPP project. The north access road intersects U.S. Highway 62/180 (U.S. 62/180) thirteen miles north of the WIPP site. The south access road intersects New Mexico Highway 128 (NM 128) four miles to the southwest.

4.1.4 Land Use

The land use surrounding the WIPP site has not changed since the preparation of Subsections 7.2.2, 8.1, and 12 of the FEIS, with the exception of land-use restrictions imposed for the WIPP project. Control Zone IV, containing approximately 11,000 acres, has been released for unrestricted use. This allows exploration for, and development of, mineral resources (oil, gas, sylvite, etc.) and permanent habitation, which were previously restricted.

The WIPP site consists of 16 sections (10,240 acres) of Federal land in Township 22 South, Range 31 East. Except for one section designated the DOE Exclusive Use Area, surface land use has remained largely unchanged during WIPP construction activities. Cattle ranching is the major land use within 10 miles of the DOE Exclusive Use Area. Mining and drilling for purposes other than support of the WIPP project are restricted within the 16-section WIPP site.

4.1.5 Air Quality

Since the preparation of Subsection 7.1.1 of the FEIS, an air-quality-monitoring program has been established. Seven classes of atmospheric gases regulated by the Environmental Protection Agency (EPA) have been monitored at the WIPP site since August 27, 1986. These gases are carbon monoxide (CO), hydrogen sulfide (H_2S), ozone (O_3), oxides of nitrogen (NO, NO_2, NO_x), and sulfur dioxide (SO_2). Total suspended particulates (TSP) are monitored in conjunction with the air-monitoring programs of the Regulatory and Environmental Surveillance Programs. The results of the monitoring program are detailed in the annual reports for the Environmental Monitoring Program (Fischer et al., 1987; 1988) which indicate that air quality in the area of the WIPP site usually meets State and Federal standards. However, the TSP standards are occasionally exceeded during periods of high wind and blowing sands. Also, the ambient-air-quality standard for sulfur dioxide has been infrequently exceeded. This condition results from sources other than the WIPP, as significant quantities of sulfur dioxide are not produced from WIPP activities.

4.1.6 Cultural Resources

As reported in Subsection 7.2.1 and Appendix H (Subsection H.1) of the FEIS, the area of the WIPP site was used by nomadic aboriginal inhabitants who left little evidence of their earlier activities. Since the publication of the FEIS, two archaeological investigations have been performed. These investigations, performed by Lord and Reynolds (1985) and Mariah Associates (1987), provide further insight into the life of the hunter-gatherers who occupied the area of the WIPP site. The 1985 investigation excavated three sites identified in the FEIS that were in areas that could have been disturbed during construction activities. These three sites were two plant-collecting and processing sites and one base camp used between 1000 B.C. and A.D. 1400. The artifacts recovered from the excavations have been placed in the Laboratory of Anthropology at the Museum of New Mexico in Santa Fe.

The 1987 investigation covered Control Zones III and IV and areas identified for possible land exchange. Sites encountered in this investigation tended to lack evident or intact features. Definable features were limited to concentrations of lithic material and other evidence of human habitation and use. No definite structures were identified. Of the 40 new sites defined, 14 were considered eligible for inclusion in the National Register of Historic Places (NRHP). Twenty-four sites were identified as having insufficient data to determine eligibility, and two sites were determined to be ineligible for inclusion in the NRHP. The eligible and potentially eligible sites have been mapped and are being avoided by the DOE in its current activities at the WIPP site.

4.1.7 Background Radiation

The background-radiation conditions in the vicinity of the WIPP site are influenced by natural sources of radiation, fallout from nuclear tests, and one local research project (Project Gnome). Prior to the WIPP project, long-term radiological monitoring programs were established in southeastern New Mexico to determine the widespread impacts of nuclear tests at the Nevada Test Site and to evaluate the effects of Project Gnome. Project Gnome which was a part of the Plowshares for Peace program, resulted in the underground detonation of a nuclear device on December 10, 1961, at a site 7.5 miles southwest of the WIPP site. The results of these monitoring programs are summarized in "Compilation of Historical Radiological Data Collected in the Vicinity of the WIPP Site" (Bradshaw and Louderbough, 1987).

The WIPP Radiological Baseline Program (RBP) was initiated in July 1985 to describe background levels of radiation and radionuclides in the WIPP environment prior to the underground emplacement of radioactive wastes. The RBP consists of five sub-programs: 1) atmospheric baseline; 2) ambient radiation (measuring gamma radiation);

3) terrestrial baseline (sampling soils); 4) hydrologic baseline (sampling surface water and bottom sediments and groundwater); and 5) biotic baseline (analyzing radiological parameters in key organisms along potential radionuclide-migration pathways). The monitoring program is described by Reith and Daer (1985).

Mean gross alpha activity in airborne particulates has shown little variation and is within the range of 1 to 3 x 10^{-15} microcuries per milliliter (μCi/ml). Mean gross beta activity in airborne particulates fluctuates but is typically within the range of 1 to 4 x 10^{-15} and 1 to 4 x 10^{-14} μCi/ml. A peak of 3.5 x 10^{-13} μCi/ml in the mean gross beta activity occurred in May 1986 and has been attributed to the Chernobyl accident in the Soviet Union. The average level of gamma radiation in the environment is approximately 7.5 microrentgen per hour (μR/hr), or approximately 66 mrem/yr. On the average, a person in the United States receives an effective dose equivalent of 200 mrem/yr from all sources of radiation. Radionuclide concentrations in soil, surface water, sediment samples, and key organisms fall within expected ranges and do not indicate any unexpected environmental concentrations. Detailed results of the RBP are provided in Banz et al. (1987) and Flynn et al. (1988).

4.2 GEOLOGY

4.2.1 Regional Geology

This section briefly discusses the regional geology within 200 miles of the WIPP site. A more detailed discussion of the regional geology is presented in Section 7 of the FEIS (DOE, 1980).

The geologic history of the region, summarized in Figure 4.1, can be subdivided into three phases following the formation of the crystalline basement complex (Precambrian rocks), which occurred 1 to 1.5 billion years before the present. The first phase, lasting until about 600 million years before the present (i.e., the beginning of the Paleozoic Era), consisted of the uplift and erosion of Precambrian rocks, forming a near-level plain within the region. The second phase, corresponding to the Paleozoic Era (lasting until approximately 230 million years before the present), was a period of almost continuous marine submergence with accumulations of continental-shelf and marine-basin deposits. By early Permian time, tectonic activity (i.e., structural deformation) that apparently occurred during Mississippian and Pennsylvanian time ceased, and basin subsidence increased. Reefs developed during the mid-Permian; eventually the Permian sea became more saline (brine), and consequently, brine-related minerals precipitated from the brine to form the thick evaporite deposits of the Castile, Salado, and Rustler Formations.

The third and present phase, beginning about 225 million years before the present, has experienced mainly continental environments and relatively stable tectonic conditions. Subsurface dissolution of the Permian evaporites probably began during this phase. Also during this third phase, periods of continental deposition alternated with erosional episodes and tilting of the sedimentary units. Unconformities caused by this tilting represent intervals during which the salt beds were tilted and subjected to downslope movement, deformation, and probable dissolution.

ERA	PERIOD	EPOCH	YEARS*		MAJOR GEOLOGIC EVENTS–SOUTHEAST NEW MEXICO REGION
			DURATION	BEFORE THE PRESENT	
CENOZOIC	Quaternary	Holocene	10,000	1,800,000	Eolian and erosional/solution activity. Development of present landscape.
		Pleistocene	1,800,000		
	Tertiary	Pliocene	3,400,000		Deposition of Ogallala fan sediments. Formation of caliche caprock.
		Miocene	18,800,000		Regional uplift and east-southeastward tilting; Basin-Range uplift of Sacramento and Guadalupe-Delaware Mountains.
		Oligocene	13,000,000		
		Eocene	16,500,000		Erosion dominant. No Early to Mid-Tertiary rocks present.
		Paleocene	11,500,000	65,000,000	Laramide "revolution." Uplift of Rocky Mountains. Mild tectonism and igneous activity to west and north.
MESOZOIC	Cretaceous		70,000,000	135,000,000	Submergence. Intermittent shallow seas. Thin limestone and clastics deposited.
	Jurassic		46,000,000	181,000,000	Emergent conditions. Erosion, formation of rolling terrain. Deposition of fluvial clastics.
	Triassic		49,000,000	230,000,000	Erosion. Broad flood plain develops.
PALEOZOIC	Permian		50,000,000	280,000,000	Deposition of evaporite sequence followed by continental red beds. Sedimentation continous in Delaware, Midland, Val Verde basins and shelf areas.
	Pennsylvanian		30,000,000	310,000,000	Massive deposition of clastics. Shelf, margin, basin pattern of deposition develops.
	Mississippian		35,000,000	345,000,000	Regional tectonic activity accelerates, folding up Central Basin platform, Matador arch, ancestral Rockies. Regional erosion. Deep, broad basins to east and west of platform develop.
	Devonian		60,000,000	405,000,000	Renewed submergence. Shallow sea retreats from New Mexico; erosion. Mild epeirogenic movements. Tobosa basin subsiding. Pedernal landmass and Texas Peninsula emergent, until Middle Mississippian.
	Silurian		20,000,000	425,000,000	
	Ordovician		75,000,000	500,000,000	Marathon–Ouachita geosyncline, to south, begins subsiding. Deepening of Tobosa basin area; shelf deposition of clastics, derived partly from ancestral Central Basin platform, and carbonates.
	Cambrian		100,000,000	600,000,000	Clastic sedimentation – Bliss sandstone.
	PRECAMBRIAN				Erosion to a nearly level plain. Mountain building, igneous activity, metamorphism, erosional cycles.

*There is no consensus on times and durations.

REF: DOE, 1980.

FIGURE 4.1

MAJOR GEOLOGIC EVENTS AFFECTING SOUTHEASTERN NEW MEXICO AND WESTERN TEXAS

These geologic events have developed the current southeastern New Mexico physiographic setting. The WIPP is located within the Pecos Valley section of the southern Great Plains physiographic province, a broad highlands that slopes gently eastward from the Basin and Range Province. (A more detailed discussion of the WIPP regional physiography is presented in FEIS Subsection 7.3.) The structural framework within which the WIPP site is located and within which the underlying Permian evaporites are situated is the Delaware Basin. The Delaware Basin is a broad, oval, north-south-trending trough with a structural relief of more than 20,000 feet on top of Precambrian basement. Deformation of the basin rocks is minor. The basin was probably developed by Early Pennsylvanian time and since the Late Permian has undergone little tectonic activity. A general stratigraphic column and cross section are shown in Figure 4.2, and major regional structures are shown in Figure 4.3.

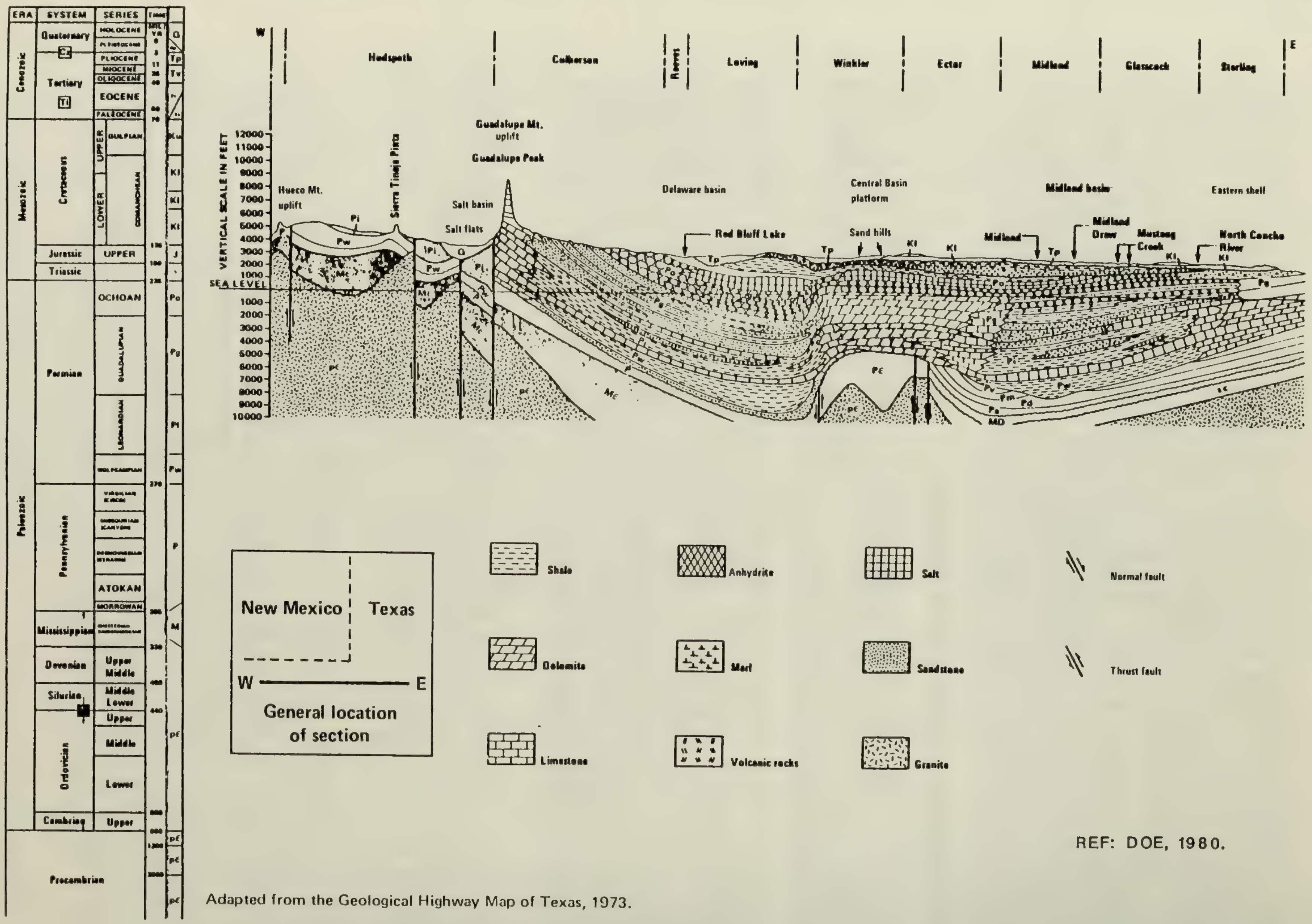
4.2.2 Stratigraphic Setting of the WIPP Site

As shown in Figure 4.3, the WIPP site is located in southeastern New Mexico, in the northern portion of the Delaware Basin. The generalized stratigraphy in the vicinity of the WIPP site is summarized in Figure 4.4. Regional stratigraphic relationships and characteristics are discussed in detail in FEIS Subsection 7.3.

The portion of the Permian stratigraphic column pertinent to the WIPP site are the upper Delaware Mountain Group and the overlying Late Permian (Ochoan) formations (Figure 4.4). The Bell Canyon Formation, the uppermost formation in the Delaware Mountain Group, is the first regionally continuous, water-bearing formation beneath the WIPP repository horizon (about 2000 feet). Near the WIPP site, the Bell Canyon Formation consists of a layered sequence of sandstones, shales/siltstones, and limestone of 980 ft or more in thickness. The sandstones and shales of the Bell Canyon Formation are overlain by the thick-bedded Permian sequence of anhydrides and halites of the Castile Formation.

The Castile Formation near the WIPP site normally contains three relatively thick units of anhydride ($CaSO_4$) and carbonate ($CaCO_3$) and two thick strata of salt halite (NaCl). Both anhydride and salt units contain abundant anhydride and/or carbonate laminae, may be strongly deformed internally, and are variable in local thickness. The thickness of the Castile Formation near the WIPP site is approximately 1310 ft.

Overlying the Castile Formation, the Salado Formation varies from 1,700 to 2,000 ft in thickness at and near the WIPP site (Figures 4.5 and 4.6). It contains 45 numbered "anhydride" marker beds of variable thickness; these beds are designated MB101 through MB145, with the numbers increasing with increasing depth. Between marker beds, the Salado Formation consists of layered halites of varying purity, with accessory minerals. The dominant accessory minerals are anhydride, clays, and polyhalite ($K_2MgCa_2(SO_4)_4 \cdot 2H_2O$). The middle portion of the Salado Formation contains potash deposits that are of commercial value. These materials are locally deposited approximately 980 ft above the underground WIPP site in the McNutt Potash Zone. The WIPP horizon is in the 26-ft-thick halite bed between Marker Beds 138 and 139.



Adapted from the Geological Highway Map of Texas, 1973.

REF: DOE, 1980.

FIGURE 4.2

GEOLOGIC COLUMN AND CROSS SECTION OF THE NEW MEXICO-TEXAS REGION

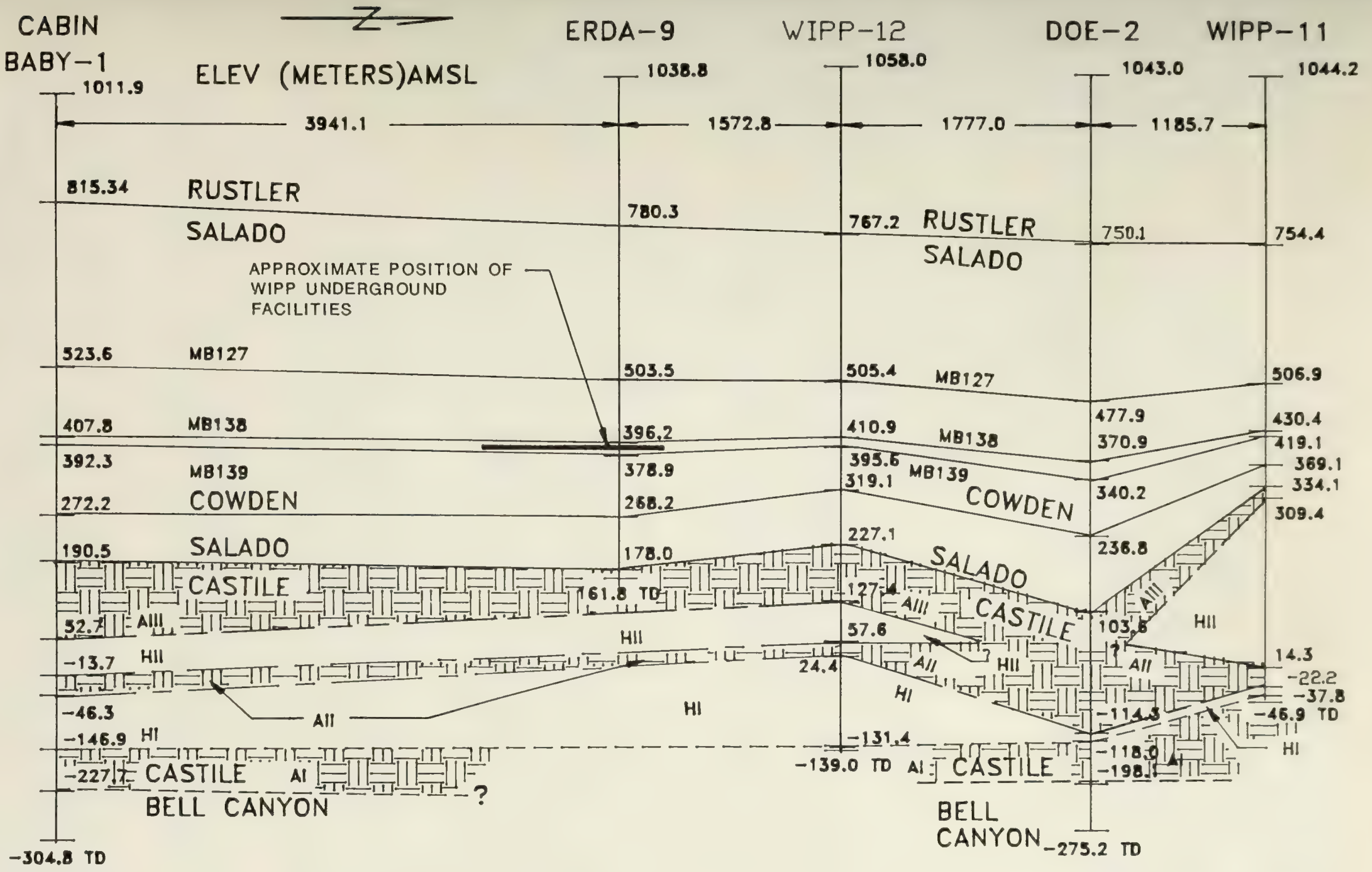
REF: DOE, 1980.

FIGURE 4.3
MAJOR REGIONAL STRUCTURES

SYSTEM	SERIES	GROUP	FORMATION	MEMBER
RECENT	RECENT		SURFICIAL DEPOSITS	
QUATERNARY	PLEISTOCENE		MESCALERO CALICHE	
			GATUNA	
TRIASSIC		DOCKUM	UNDIVIDED	
PERMIAN	OCHOAN		DEWEY LAKE RED BEDS	
			RUSTLER	Forty-niner
				Magenta Dolomite
				Tamarisk
				Culebra Dolomite
				unnamed
			SALADO	
			CASTILE	
	GUADALUPIAN	DELAWARE MOUNTAIN	BELL CANYON	
			CHERRY CANYON	
			BRUSHY CANYON	

REF: BEAUHEIM, 1987c.

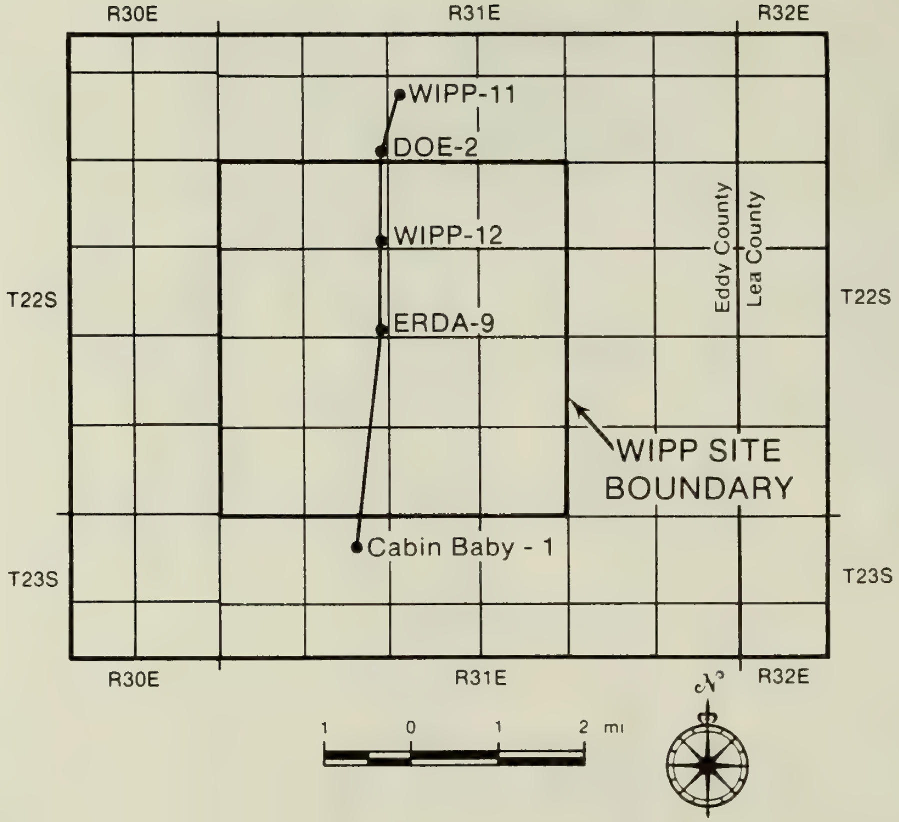
FIGURE 4.4
GENERALIZED STRATIGRAPHIC COLUMN FOR THE WIPP SITE



NOTES: 1) BOREHOLE LOCATIONS USED ARE SHOWN ON FIGURE 4.6.
2) ELEVATIONS AND BOREHOLE SPACINGS ARE IN METERS.

REF: LAPPIN, 1988.

FIGURE 4.5
GENERALIZED STRATIGRAPHIC CROSS SECTION OF THE SALADO AND CASTILE FORMATIONS BETWEEN BOREHOLES CABIN BABY-1 AND WIPP-11



REF: LAPPIN, 1988.

FIGURE 4.6
BOREHOLE LOCATIONS FOR GENERALIZED STRATIGRAPHIC
CROSS SECTION OF THE SALADO AND CASTILE FORMATIONS

The Salado Formation is overlain by the Rustler Formation, also of Ochoan age. The Rustler contains five members, two of which, the Magenta and the Culebra Dolomites, are water-bearing zones and contain amounts of gypsum. The other three members of the Rustler Formation (the unnamed lower member, the Tamarisk Member, and the Forty-niner Member in upward succession) consist of varying proportions of anhydride, siltstone/claystone, and halite. The Rustler Formation ranges from 270 ft to 430 ft in thickness at the WIPP site, depending on the extent of evaporite dissolution and/or depositional variability. The Rustler Formation at the WIPP is overlain by the Dewey Lake Red Beds (the uppermost unit of the Ochoan Series) consisting largely of siltstones and claystones, with subordinate sandstones. The unit is approximately 100 ft to 560 ft thick at and near the WIPP site, varying at least in part due to post-depositional erosion.

4.3 HYDROLOGY AND WATER QUALITY

The following subsection describes the hydrologic and geochemical setting at the WIPP site. The purposes of SEIS Subsection 4.3.1, General Setting, are to provide a general overview of the WIPP site hydrology, to provide a summary of the hydrologic conclusions reached at the time of the FEIS, and to provide a description of the current understanding of hydrologic and geochemical issues. SEIS Subsections 4.3.2, 4.3.3, 4.3.4, and 4.3.5 discuss data collection and interpretation efforts conducted since 1980 and how these efforts apply to the hydrologic and geochemical conditions of the Rustler, Salado, Castile, and Bell Canyon formations.

4.3.1 General Setting

4.3.1.1 Hydrologic Overview. The WIPP is located in a portion of the Unglaciated Central Region that includes some of the least productive aquifers in the United States. Consequently, the low productivity and general aridity of the area puts even greater emphasis on using these marginal aquifers to the maximum benefit. Section 7 of the FEIS (DOE, 1980) describes the regional hydrology and water quality in detail. This section should be referred to by the reader to set the context for an understanding of the WIPP site hydrology.

The geologic units of hydrologic interest to the WIPP site, in ascending order, include the Bell Canyon Formation of the Delaware Mountain Group, the thick-bedded sequence of anhydrides and halites of the Castile Formation, the thick-bedded predominantly halites of the Salado Formation (including the Facility Horizon), and the overlying Rustler Formation.

The Bell Canyon Formation is of interest because it is the first regionally continuous water-bearing unit beneath the WIPP. The Castile Formation provides a hydrologic barrier underlying the Salado Formation, though it may contain pressurized brine deposits.

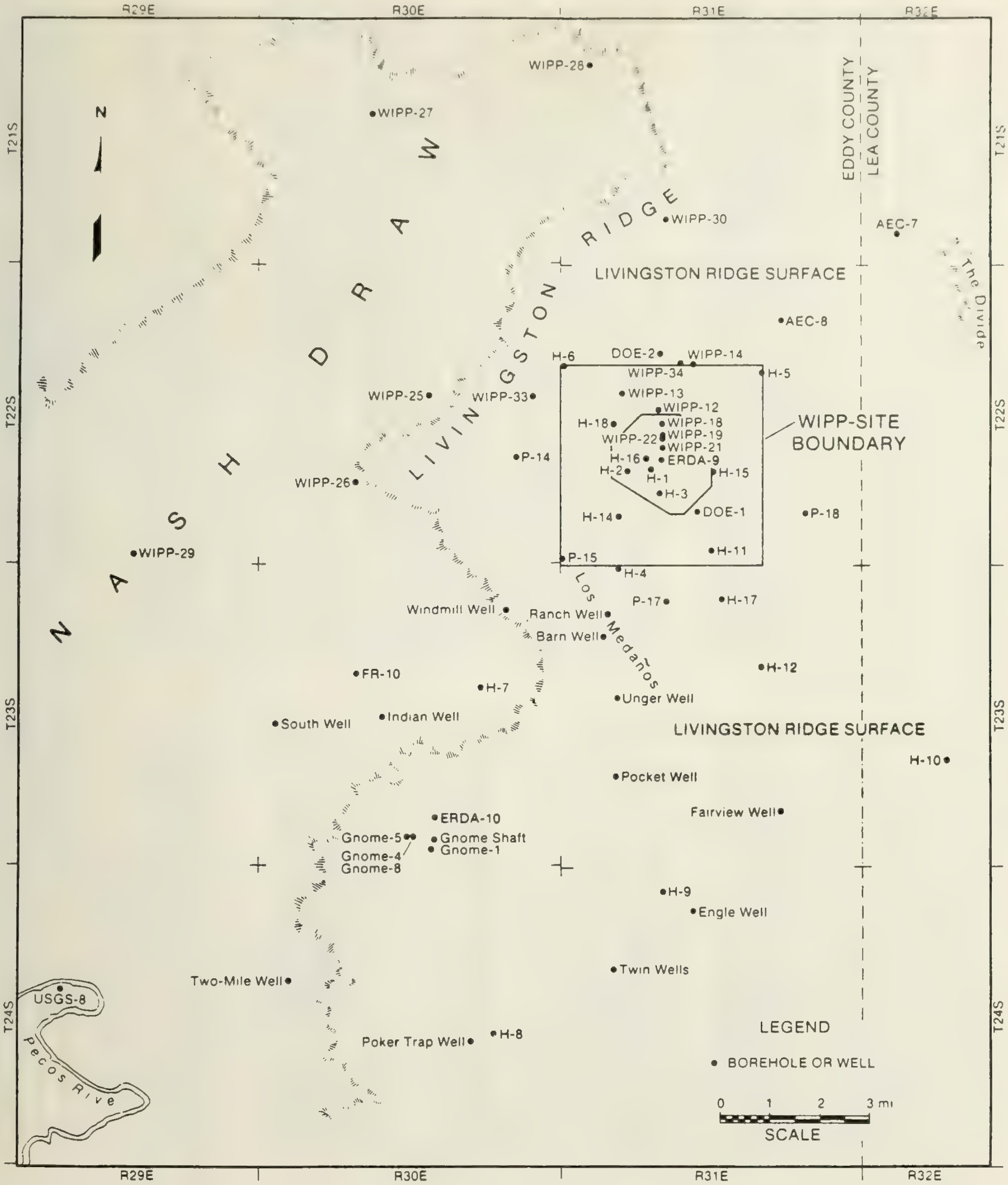
The Culebra Dolomite of the Rustler Formation is the first laterally continuous unit located above the WIPP underground facility to display hydraulic conductivity of any significance. Barring direct breach to the surface, the Culebra Dolomite provides the most direct pathway between the WIPP facility and the accessible environment. The hydrology and fluid geochemistry of the Culebra Dolomite are very complex and as a result have received a great deal of study in WIPP site characterization before and since 1980 (LaVenue et al., 1988; Haug et al., 1987). A map showing the borehole locations referred to throughout the following text is presented in Figure 4.7.

4.3.1.2 Hydrologic and Geochemical Issues. A number of issues have been developed regarding the hydrogeologic and geochemical characteristics of the WIPP site. These issues were either considered in the FEIS or developed in response to new data generated by shaft exploration and excavation activities conducted since the completion of the FEIS. A summary of the hydrologic and geochemical issues, the assumptions made regarding these issues in the FEIS, and current understanding of these issues is presented in Table 4.1. The current understanding of the hydrologic and geochemical issues is incorporated into the analysis of potential long-term performance impacts discussed in Subsection 5.4.

4.3.2 **Salado Formation**

The Salado Formation is a major salt-bearing formation and is the horizon within which the WIPP underground facility is located. The FEIS assumed that the disposed waste would be compacted within the salt because of the stress-induced creep of salt (i.e., closure of the tunnels due to movement of the salt) and would remain dry because of the lack of interstitial fluids. The FEIS also assumed that the gas permeability of the salt would be sufficient to dissipate the gas generated by the waste. Subsequent to the FEIS, hydrologic investigations in the underground facility and hydrologic testing adjacent to the air-intake shaft have provided additional information about these assumptions. The following subsections summarize the results of the hydrologic and geochemical studies of the Salado that have been completed since the FEIS. Subsection 4.3.2.1 discusses the current understanding of brine inflow and the gas-dissipation potential. Subsection 4.3.2.2 discusses the hydrologic testing that has been conducted in the WIPP underground facility. Subsection 4.3.2.3 summarizes the results of the hydrologic testing at the waste-handling shaft. Subsection 4.3.2.4 discusses the characteristics of Marker Bed 139.

4.3.2.1 Brine Inflow and Gas Dissipation Potential. Brine-related studies that were completed at the time of the FEIS indicated that: 1) the only water in Salado halites was present in fluid inclusions and hydrous minerals and no intercrystalline brines were believed to be present; 2) brine flow would be driven by temperature gradients with no long-term steady-state flow; and 3) there would be no need for engineered backfill within the repository to control brine inflow or interactions between brine and the waste. Since the FEIS, test excavations into the target horizon showed that brine "weeps" often formed on mined faces within a few days of excavation and that salt crusts continued to form on open faces for months (Deal and Case, 1987). Nowak and McTigue (1987) measured flow rates ranging from a few milliliters to 0.5 L/day and estimated an average steady-state flow of about 1.6 L/day/m^2. Mine ventilation evaporates the brine-water content in almost all areas. Also, long-term observations show that most inflows decrease markedly over time and many cease entirely. Because of the very slow response times, steady-state flow conditions may be determinable only from many years of observation (Deal, 1988).



REF: LAPPIN, 1988.

FIGURE 4.7
HYDROLOGIC BOREHOLES AND WELLS
AT AND NEAR THE WIPP SITE

TABLE 4.1 Hydrologic issues: FEIS vs. Current (Modifed from Lappin et al., 1989)

Hydrologic issue	Assumptions or treatment in the FEIS	Present understanding
1. Salado brine flow and brine permeability	a. Water assumed present only in fluid inclusions and hydrous minerals; grain boundaries assumed dry.	a. Grain-boundary brines distinct from fluid inclusions. Salado probably hydrologically saturated.
	b. Brine inflow only due to thermal gradients resulting from excavation and waste emplacement; very limited volumes, with zero flow at long times. Pressure gradients were not considered as a driving mechanism for brine inflow.	b. Major factor is flow of grain-boundary fluids due to pore-pressure gradients resulting from excavation; experimental results to date modeled assuming Darcy flow, which implies nonzero long-term inflow; possible uncertainties due to stratigraphic effects, two-phase flow, and non-Darcy-flow model recognized but not yet quantified; Darcy-flow model probably overpredicts brine inflow, but still indicates brine-based slurry is highly improbable.
	c. Far-field brine permeability not relevant since unit interpreted to be unsaturated.	c. Far-field brine permeability probably less than 10^{-20} to 10^{-21} m^2; <u>may</u> be effectively zero in undisturbed region.
2. Salado gas permeability and gas storage properties	a. Far-field gas permeability of Salado salt considered; appeared adequate to dissipate the gas potentially generated by waste.	a. Far-field gas permeability probably less than 10^{-20} to 10^{-21} m^2, and grain-boundary brines pressurized to between hydrostatic and lithostatic pressure; very difficult to dissipate any significant volumes of gas generated within the underground workings, because of the extremely low permeability.
	b. No major concern with gas pressures within facility.	c. Combination of potential gas-generation rates and very low far-field permeability will probably result in gas pressures exceeding lithostatic load unless they are relieved by (1) room reexpansion; (2) gas storage in disturbed-rock zone adjacent to underground workings; (3) gas storage in Marker Bed 139 and along other stratigraphic contacts near the WIPP facility horizon; and/or (4) a combination of gas migration past the panel seals and up shafts into adjacent marker beds.
3. Salado brine geochemistry	a. Intergranular brines not recognized; brines A and B defined for experimental purposes; brine A is K, Mg-rich, brine B is high NaCl brine. Neither one was from the repository level.	a. Considerable variability of Salado brines identified; standard brine identified is similar to brine B, but less rich in K and Mg, higher in Na, Cl and B, brine standard defined appears to be near saturation with anhydrite, gypsum, and halite; brines collected within WIPP underground workings often evolve gas, thought to be mainly nitrogen.
4. Hydrology of the Castile Formation; presence and character of Castile brine reservoir beneath WIPP underground workings	a. Castile brines known at drill holes ERDA-6 and Belco, but the FEIS concluded that Castile brine was probably not present beneath underground workings; effects of pressurized-brine occurrence in the Salado considered qualitatively.	a. Pressurized brines are assumed to be present beneath WIPP waste-emplacement panels, based on data from combination of drill holes and geophysical studies; properties of brine occurrence are assumed to be those interpreted for the WIPP-12 reservoir.
5. Hydrology of the Bell Canyon Formation and relationship of the hydraulic heads of the Bell Canyon and Rustler	a. Although possibility of downward flow was recognized, it was assumed that flow after the interconnection of the Bell Canyon and the Rustler would be upward into the Rustler (FEIS scenario).	a. Based on interpretation of relative heads at drill holes Cabin Baby-1 and DOE-2, it is concluded that flow would be downward if Bell Canyon and Rustler were interconnected; due to low local permeability of Bell Canyon flow in this unit would be very slow and is not considered here.

TABLE 4.1 Concluded

Hydrologic issue	Assumptions or treatment in the FEIS	Present understanding
6. Rustler Formation hydrology, geochemistry, and numerical modeling	a. Three water-bearing zones recognized, based on testing at eight locations.	a. A total of 41 locations tested to date, indicating presence of five water-producing units.
	b. Culebra and Magenta Dolomites known to range widely in transmissivity, but thicknesses were combined for purposes of numerical modeling; uniform transmissivity to Rustler Formation, as an integrated hydrostratigraphical unit was assigned in WIPP site area.	b. Culebra Dolomite still interpreted to dominate flow in site area. Culebra transmissivity variable by approximately three orders of magnitude; total range of reported transmissivities (T) from $\leq 2 \times 10^{-7}$ m^2/s to $>10^{-4}$ m^2/s; all measured transmissivities included as point values in numerical estimates of transmissivity distribution; zone of relatively high transmissivities present in southeastern portion of site; final regional-scale testing of the Culebra Dolomite completed in 1988, but interpretation not yet completed.
	c. Culebra Dolomite known to be locally fractured, but modeled as porous medium, with uniform porosity of 0.10.	c. Local flow and transport behavior affected by fracturing where $T \geq 10^{-6}$ m^2/s; distances over which fracturing plays a role dependent on local properties, especially in southeastern part of site; under some conditions fractures may dominate transport to location outside the site area; measured matrix porosities range from 0.07 to > 0.3.
	d. Flow within Culebra interpreted to be essentially north-south in site area, with final discharge at Malaga Bend, southwest of the WIPP site; interpretation based on modeling of flow from interpreted freshwater heads.	d. Modern flow within Culebra interpreted to be largely north-south in Site area, but dominated by flow in zone of relatively high transmissivity in southeastern portion of Site; ultimate discharge not clear at present; interpretation based on modeling which includes effects of variable brine density.
	e. Head potential known to vary across hydrostratigraphic units; however, it was assumed for numerical modeling that Rustler carbonates were completely confined and at steady state.	e. Head potentials between units known to be laterally variable; limits to vertical flow considered qualitatively: present modeling assumed confined steady-state flow on 10,000 year time scale; except for disturbance due to Castile brine reservoir; however, it is recognized that Rustler hydrologic setting is transient on 10,000-year time scale; where defined, relative head potentials and geochemistry within Rustler not consistent with modern infiltration from surface at WIPP.
	f. Rustler water salinity known to be variable (3000 to 60,000 ppm TDS), but effects could not be considered in numerical modeling.	f. Total range of TDS in Rustler waters at the WIPP site estimated as 4000 to > 300,000 mg/L, Culebra waters range from approximately 10,000 to > 200,000 mg/L; need for careful and repetitive sampling of groundwaters recognized.

A variety of investigations have been undertaken within the WIPP underground facility since the FEIS. Geophysical studies aimed at characterizing the disturbed rock zone near the excavation began during construction and will continue through the WIPP operational phase. Available results (Borns and Stormont, 1987; Pfeifer, 1987) indicate that there is variability in both the water content and the hydrologic properties of the Salado Formation near the underground excavations and that the water content of Salado salts far from the excavations appears to be approximately twice that estimated at the time of the WIPP studies in the Site Preliminary Design Validation (SPDV) phase.

The results of a series of electrical conductivity measurements in the WIPP underground horizon (Pfeifer, 1987) indicate a water content of approximately 1 percent (by weight) near the mined opening and 2 percent in the far field. However, only a fraction of this water may be mobile as brine inflow under repository pressure gradients (Deal and Case, 1987).

Estimated water contents of samples analyzed during SPDV activities ranged from a mean of 0.6 weight percent to a maximum of 1.8 weight percent, compared to mean and maximum values of 0.22 and 1.06 weight percent estimated from measurements on core from drill hole ERDA-9 (DOE, 1983). The earlier estimates were made either on core material or on hand specimens collected during mining, which may have excluded some portion of interstitial fluid. Detectable fluid flow into the facility has resulted from large mining-induced pressure gradients and proves to be greater than expected given the estimates of the water content in the Salado Formation obtained during the SPDV.

Two studies have been undertaken to characterize brine flow into the facility. Deal and Case (1987) reported a long-term study designed to evaluate inflow at ambient temperatures. The second study (Nowak and McTigue, 1987) also provided ambient-temperature inflow data.

The Deal and Case study indicated that variable amounts of both brine and dissolved gas can be intersected in drillholes extended from the WIPP facility. The maximum flow rate encountered has been approximately 0.5 L/day. One drillhole produced approximately 235 liters of brine at a rate of 0.2 L/day. This hole apparently intersects Marker Bed 139, which contains numerous near-field fractures that resulted from the construction of the WIPP. Most of the measured flow rates ranged from a few thousandths to a few tenths of a liter per day.

Nowak and McTigue (1987) investigated flow into one 36-inch- and three 30-inch-diameter holes. Liquid was continuously removed from the holes by the use of dry nitrogen. The results indicate a flux of approximately 1.5 cm^3/day/m^2 of excavation wall. These brine-inflow rates were used as a basis to estimate hydraulic conductivities for the near-field WIPP Salado host rock. Using a Darcy-flow model and assuming a porous and elastic medium, hydraulic conductivities in the ranges of 10^{-13} to 10^{-14} m/sec (10^{-20} to 10^{-21} m^2) were estimated (Nowak and McTigue, 1987; Nowak et al., 1988).

Additional calculations based on direct in situ hydraulic-conductivity investigations indicate that the FEIS may have greatly overestimated the far-field hydraulic conductivity of the Salado Formation. Current estimates of the far-field hydraulic conductivity, based on direct measurements at the waste-handling shaft and in the test rooms, indicate that the values are in the range of 10^{-13} to 10^{-15} m/sec (10^{-20} to 10^{-22} m^2) (Peterson et al., the values are in the range of 10^{-13} to 10^{-15} m/sec (10^{-20} to 10^{-22} m^2) (Peterson et al., 1987; Saulnier and Avis, 1988; Tyler et al., 1988). A more detailed discussion of Salado permeability testing and brine-inflow data is presented in Appendix E.

Although these test results indicate that the permeability and the brine content of the Salado are very low, the hydraulic characteristics of the Salado Formation have not yet been clearly defined. The hydraulic uncertainties include 1) whether the driving mechanism for brine flow is a far-field-driven hydraulic system or a system limited to the disturbed-rock zone, where mining-induced pressure gradients drive the brine through zones of increased local permeability due to fracturing; 2) whether a gas-driven, two-phase behavior is a factor; and 3) whether a porous-media (Darcy) flow or a non-Darcy flow is the predominant process. Experimental data to date have been modeled successfully with the assumption of Darcy flow. The two to three years of underground observation have not been sufficient to distinguish between Darcy and non-Darcy flow.

In response to these uncertainties, two general conceptual models are proposed for brine inflow. These conceptual models include a conventional Darcian flow model (see, for example Bredehoeft, 1988; Nowak et al., 1988), assuming a porous and elastic medium, and a non-Darcian (plastic-medium) model that considers the plastic nature of the rock salt and limits flow to the bedded evaporites that have been disturbed by the WIPP underground excavations. In the non-Darcian conceptual model, the flow of brine into the WIPP underground facility would decrease to zero prior to the saturation of the WIPP rooms and panels. The Darcian-flow model (which includes flow throughout the Salado Formation) may be a conservative model in that it assumes that far-field flow exists and predicts maximum brine accumulations (i.e., potential saturation of the WIPP excavation at some time after the WIPP is closed). The results obtained with the Darcian brine-inflow model are presented in Subsection 5.4.2.4.

A recent concern related to brine inflow is that the compaction of the waste within the disposal rooms will be incomplete or interrupted and that brine will mix with the waste to form a slurry. The slurry is envisioned as a watery mixture of insoluble matter that is easily transported through natural or man-induced pathways. The formation of waste mixtures with such fluidity seems to be very unlikely. The brine-inflow modeling indicates that the backfill and the waste will reach a sufficiently compacted state to become solid-like before they become saturated in brine.

The most important potential response to brine inflow is the generation of gas from the waste materials. If sufficient brine is present, the combination of microbial activity, canister corrosion, metal-waste corrosion, and radiolysis will produce large quantities of gas (see Subsection 5.4). Gas generation may create a situation where the repository rooms are unsaturated with brine but are pressurized by gas to levels approaching those of lithostatic pressure. The current brine-inflow estimates indicate that sufficient quantities of brine will be available for gas generation. However, it should be noted that current estimates are conservative because of parameter-value selections and because of fundamental model assumptions. If brine-inflow rates are significantly lower than the current estimates, gas production may be limited, and the final repository state may be quite different from ultimately saturated pressurized system. In order to predict the final state of the repository with a high level of confidence, brine inflow must be characterized as fully as possible.

This leads to the second issue of concern in the Salado Formation, the potential for dissipation of waste-generated gas during the postclosure period. If gas pressures approach lithostatic levels within the repository, and if seals at the repository level are not by-passed, fractures are expected to form when the least principal stress is exceeded in the surfaces of the excavations and propagate into the Salado Formation. Results from fracturing experiments by Wawersik and Stone (1986) indicate that there was no preferential direction for fracture propagation, though at the WIPP facility horizon, previously fractured zones like Marker Bed 139 may provide a preferential pathway for gas migration.

For pressures approaching lithostatic levels to develop, given the assumption that gas generation will occur, far-field permeabilities must be at or near zero. At the time the FEIS was published, the far-field gas permeability of the Salado Formation appeared to be sufficient to dissipate waste generated gas pressures. Current information concerning the gas-transport properties of the Salado Formation indicates that the far-field permeabilities may be even lower than the present estimate (10^{-20} to 10^{-21} m^2), that is, significantly less than previously estimated. (See earlier discussion regarding permeabilities.) Consequently, the far-field permeability values for the Salado Formation may not be sufficient to dissipate generated gas pressures within the WIPP facility to levels less than those of lithostatic pressures should conditions be favorable for the generation of large volumes of gas.

One key to understanding the final state of the repository with regard to gas pressure and degree of saturation is further detailed characterization of brine inflow. Additional investigations will be conducted during the Test Phase to refine the understanding of Salado far-field permeabilities and brine inflow.

4.3.2.2 Hydrologic Testing of the Salado Formation at the Facility Horizon. The permeability characteristics of the Salado Formation need to be understood in order to predict brine-inflow rates and to evaluate the extent to which gas pressures can be dissipated. At the time the FEIS was written, hydraulic tests had been conducted in the Salado Formation at two locations, drillholes ERDA-9 and AEC-7 (DOE, 1980; Tyler et al., 1988). The permeability values estimated from these tests ranged from 10^{-17} to 10^{-18} m^2 (10^{-10} to 10^{-11} m/sec). After the excavation of the WIPP underground facility, a number of inflow or permeability tests were conducted at the facility horizon. The brine-inflow tests were previously discussed in Subsection 4.3.2.1 (Deal and Case, 1987; Nowak and McTigue, 1987). The gas-permeability tests reported by Peterson et al. (1987) will be briefly discussed here. A more detailed presentation of post-FEIS Salado Formation permeability testing data is in Appendix E. Results of permeability testing within the Salado Formation from test installations within the WIPP facility are generally consistent with estimates of far-field permeabilities that range from 10^{-20} to 10^{-22} m^2 (10^{-13} to 10^{-15} m/sec). The results of these tests are consistent in that they indicate far-field permeabilities in the Salado Formation to be 1000 to 10,000 times lower than those assumed at the time of the FEIS. The pre-FEIS surface permeability tests in the Salado (drillholes ERDA-9 and AEC-7) were reevaluated and determined to be not defensible for a number of reasons, including the following: 1) the pressure-stabilization periods preceding the tests were too short to allow adequate equilibration between borehole and formation pressure; 2) individual tests were also too short to allow representative formation responses to develop; and 3) the formation pore space was assumed to be filled with gas (Lappin et al., 1989).

Gas-flow permeability tests that were conducted from the WIPP underground facility can be grouped into three sets: 1) 1984 tests, 2) tests in the N1420 drift, and 3) tests in the first storage panel. Gas-flow tests were conducted from horizontal, vertical, and angular boreholes drilled from WIPP drifts. The results of these tests are presented in Tables 4.2 through 4.5. It should be noted that most of these tests were conducted a relatively short distance from the underground facility and clearly show the effects of the disturbed-rock zone. The conclusions that can be drawn from these tests are also presented in Appendix E.

The brine-inflow test boreholes, the waste-handling shaft tests described in the following section, and the few gas-flow tests that may have intercepted far-field conditions represent a limited data base for the characterization of the hydraulic properties of the Salado Formation. Currently, a plan for an extensive five-year Test Phase is being developed. Included in this plan is a description of the hydraulic investigation program (i.e., far-field brine-inflow tests, room tests, etc.) that is needed to understand the hydraulic characteristics of the Salado Formation.

4.3.2.3 Hydrologic Testing Adjacent to the WIPP Waste-Handling Shaft. The long-term performance of the WIPP facility depends on the effectiveness of the shaft seals. Present planning requires the emplacement of shaft seals in both the Salado Formation and the unnamed lower member of the Rustler Formation.

A preliminary series of hydrologic tests were conducted at several levels in the WIPP waste-handling shaft in 1987 (Saulnier and Avis, 1988) to evaluate the hydraulic characteristics of these units within the vicinity of a shaft. The objectives of these tests were to

- Evaluate the extent of the disturbed-rock zone extending from the concrete liner of the shaft

- Estimate the pressure and the radial extent of the hydrologic response to the stresses induced by shaft construction

- Estimate the far-field hydraulic properties of the lower unnamed member of the Rustler Formation and selected levels in the Salado Formation.

The tests were conducted at depths of 782 and 805 ft in the unnamed member of the Rustler Formation and at depths of 850 and 1320 ft in the Salado Formation. The materials tested in the Rustler Formation include mudstone and claystone. The materials tested in the Salado Formation include halite, anhydrite, and polyhalite. Testing was conducted at drillholes, extending laterally into three test zones: Zone 1 extended from approximately 18 to 42 ft from the shaft, Zone 2 extended from approximately 12 to 20 ft, and Zone 3 extended from approximately 5 to 15 ft. The instrumentation used during the testing is described by Stensrud et al. (1988).

The results of the hydraulic testing at the waste-handling shaft are summarized in Table 4.6 and Figures 4.8 and 4.9. The range of hydraulic-conductivity values presented on

TABLE 4.2 Summary of 1984 Phase 2 Underground Facility Gas Flow Test Results (Modified from Stormont et al., 1987)

					Test Interval			Permeability Analysis		
					Distance from tunnel					
	Hole Number	Orientation	Location with respect to tunnel	Geologic Features	Minimum	Maximum	Mean	Transient Method K(uD)	Porosity	Steady-State Method $K(m^2)$
1	4PD01	Down	Center	Marker bed	1.2	2.8	2.00	NA[a]	NA	$> 9.87 \times 10^{-13}$
2	4PD02	Down	Near side	Marker bed	1.5	2.8	2.15	NA	NA	$< 9.87 \times 10^{-18}$
3	4PU04	Up	Center	Seam B	1.3	3.4	2.35	NA	NA	9.87×10^{-16}
4	4PU01	Up	Near side	Seam B	2.8	4.3	3.55	NA	NA	$< 9.87 \times 10^{-18}$
5	4PU02	Up	Center	Seam A	3.4	5.0	4.20	NA	NA	$< 9.87 \times 10^{-18}$
6	DPD01	Down	Removed	Marker bed	9.3	12.5	10.90	NA	NA	$< 9.87 \times 10^{-18}$

[a] Not applicable

TABLE 4.3 Summary of N1420 Initial Tests (Modified from Stormont et al., 1987)

					Test Interval			Permeability Analysis		
					Distance from tunnel			Transient		Steady State
	Hole Number	Orientation	Location with respect to tunnel	Geologic Features	Minimum	Maximum	Mean	K(uD)	Method Porosity	Method $K(m^2)$
1	NPD02	Down	Center	Marker bed	1.0	2.6	1.80	NA[a]	NA	2.96×10^{-16}
2	NPD05	Down	Center	Marker bed	1.0	2.8	1.90	NA	NA	4.94×10^{-17}
3	NPD05	Down	Center	Marker bed	1.0	2.8	1.90	NA	NA	8.39×10^{-17}
4	NPD04	Down	Center	Marker bed	1.0	2.9	1.95	NA	NA	5.13×10^{-17}
5	NPD06	Down	Intersect	Marker bed	1.0	2.9	1.95	NA	NA	8.29×10^{-14}

[a] Not applicable

TABLE 4.4 Summary of N1420 Follow-up (Modified from Stormont et al., 1987)

					Test Interval			Permeability Analysis		
	Hole Number	Orientation	Location with respect to tunnel	Geologic Features	Distance from tunnel units Minimum	Maximum	Mean	Transient Method K(uD)	Porosity	Steady-State Method $K(m^2)$
1	L2CU1	Up	Center	Seam B	1.1	2.8	1.95	NA[a]	NA	$> 3.95 \times 10^{-12}$
2	NPU01	Up	Center	Halite rocks	0.5	0.9	0.65	NA	NA	$< 8.59 \times 10^{-17}$
3	NPD05	Down	Center	Halite rocks	0.4	0.8	0.60	NA	NA	$< 7.90 \times 10^{-20}$
4	NPD04	Down	Center	Halite rocks	0.5	0.9	0.65	NA	NA	$< 2.66 \times 10^{-19}$
5	NPD03	Down	Center	Halite rocks	0.3	0.7	0.50	NA	NA	$< 5.13 \times 10^{-15}$
6	2PD01	Down	Center	Halite rocks	0.4	0.8	0.55	NA	NA	$< 1.78 \times 10^{-15}$
7	NPD12	Down	Center	Halite rocks	0.4	0.8	0.55	NA	NA	$< 6.81 \times 10^{-17}$
8	NPD07	Down	Intersect	Halite rocks	0.4	0.8	0.55	NA	NA	$< 3.26 \times 10^{-16}$
9	NPD06	Down	Intersect	Halite rocks	0.4	0.8	0.57	NA	NA	$< 3.16 \times 10^{-15}$
10	NPD09	Down	Removed	Halite rocks	0.5	0.9	0.65	NA	NA	$< 1.38 \times 10^{-17}$
11	NPD08	Down	Near side	Halite rocks	0.5	0.9	0.65	NA	NA	$< 1.48 \times 10^{-13}$
12	NPD02	Down	Center	Halite rocks	0.5	0.9	0.65	NA	NA	$< 5.53 \times 10^{-15}$
13	NPD01	Down	Center	Halite rocks	0.5	0.9	0.65	NA	NA	$< 1.58 \times 10^{-18}$
14	L2CU1	Up	Center	Halite rocks	0.5	0.9	0.67	NA	NA	$< 3.36 \times 10^{-15}$
15	NPD02	Down	Center	Marker bed	1.0	2.5	1.75	NA	NA	8.59×10^{-16}
16	NPD02	Down	Center	Marker bed	1.0	2.5	1.75	NA	NA	7.50×10^{-16}
17	NPD03	Down	Center	Marker bed	1.0	2.7	1.85	NA	NA	4.05×10^{-18}
18	NPD05	Down	Center	Marker bed	1.0	2.8	1.90	NA	NA	5.53×10^{-16}
19	NPD05	Down	Center	Marker bed	1.0	2.8	1.90	NA	NA	3.26×10^{-16}
20	2PD01	Down	Center	Marker bed	1.0	2.9	1.95	NA	NA	$> 3.95 \times 10^{-12}$
21	NPD12	Down	Center	Marker bed	1.0	2.9	1.95	NA	NA	1.38×10^{-17}
22	NPD07	Down	Intersect	Marker bed	1.0	2.9	1.95	NA	NA	$> 3.95 \times 10^{-12}$
23	NPD06	Down	Intersect	Marker bed	1.0	2.9	1.95	NA	NA	$> 3.95 \times 10^{-12}$
24	NPD04	Down	Center	Marker bed	1.0	2.9	1.95	NA	NA	2.66×10^{-16}
25	NPD09	Down	Removed	Marker bed	1.0	3.0	2.00	NA	NA	3.45×10^{-19}
26	NPD08	Down	Near side	Marker bed	1.0	3.7	2.35	NA	NA	$< 6.81 \times 10^{-20}$
27	NPD01	Down	Center	Marker bed	1.0	3.7	2.35	NA	NA	4.15×10^{-17}
28	NPU01	Up	Center	Seam B	1.0	4.3	2.65	NA	NA	9.18×10^{-16}
29	NPU01	Up	Center	Seam B	1.0	4.3	2.65	NA	NA	2.37×10^{-16}
30	NPD10	Down	Removed	Marker bed	1.0	4.7	2.85	NA	NA	$< 8.59 \times 10^{-20}$

[a] Not applicable

TABLE 4.5 Summary of First Panel Tests (Modified form Stormont et al., 1987)

Hole Number		Orientation	Location with respect to tunnel	Geologic Features	Test Interval			Permeability Analysis		
					Distance from tunnel units			Transient Method		Steady-State Method
					Minimum	Maximum	Mean	K(uD)	Porosity	K(m^2)
1	SPD06	Down	Center	Marker bed	1.3	3.3	2.30	NA[a]	NA	1.28×10^{-17}
2	SPU01	Up	Center	Seam B	1.3	3.3	2.30		Produced gas	
3	SPU06	Up	Center	Seam B	1.3	3.3	2.30		Produced gas	
4	SPU02	Up	Center	Seam B	1.3	3.3	2.30		Produced gas	
5	SPU05	Up	Center	Seam B	1.3	3.3	2.30		Produced gas	
6	SPD02	Down	Center	Marker bed	1.3	3.3	2.30	NA	NA	6.71×10^{-20}
7	SPD05	Down	Center	Marker bed	1.3	3.3	2.30	NA	NA	2.76×10^{-17}
8	SPD01	Down	Center	Marker bed	1.3	3.3	2.30	NA	NA	$< 2.96 \times 10^{-19}$
9	SPU04	Up	Center	Seam B	1.3	3.3	2.30	NA	NA	2.17×10^{-19}
10	SPU03	Up	Center	Seam B	1.3	3.3	2.30		Produced gas	
11	SPD04	Down	Center	Marker bed	1.3	3.3	2.30	NA	NA	6.42×10^{-19}
12	SPD03	Down	Center	Marker bed	1.3	3.3	2.30	NA	NA	1.28×10^{-19}

[a] Not applicable

presented on Table 4.6 is narrow, and the values are on the order of those expected in the far field (10^{-13} to 10^{-15} m/s). No discernible trend of an increase in hydraulic conductivity from Zone 1 to Zone 3 exists on the basis of these relatively short-term tests. The results of the testing appear to indicate that no disturbed-rock zone exists (i.e., no more than 5 ft into the rock) as the result of shaft construction.

Shaft construction has apparently formed a cone of depression in the hydraulic systems in the units adjacent to the waste-handling shaft. Fluid pressures measured around the shaft at the 805 and 1320-ft levels indicate that lowered pressures extend outward approximately one shaft diameter (Figure 4.9). The pressure release is consistent with responses noted in the Culebra Dolomite during the construction of exploratory shafts (Haug et al., 1987). Saulnier and Avis (1988) report that fluid-pressure profiles at the 782-ft and 850-ft levels may not be reliable because of possible equipment malfunctions.

The results of this shaft hydrologic testing program indicate a limited zone of disturbance in the vicinity of the shaft. Multiple arrays of test holes and possibly non-intrusive geophysical methods could provide additional data (Lappin, 1988).

4.3.2.4 Marker Bed 139 Structural Studies Near the WIPP Facility. Marker Bed 139 (MB139) is an anhydrite marker bed that is approximately 3 ft. thick. This marker bed lies about 3.3 ft below the floor of the underground waste disposal area. Because of concern that the undulations noted on the top of MB139 might be the result of post-depositional deformation, a detailed study of MB139 began in 1983 (Jarolimek et al. 1983). Studies reported by Jarolimek et al. (1983) and Borns (1985), however, indicate that the undulations are depositional in origin rather than having been formed by post-depositional geologic stresses.

Observations of the floors of the oldest WIPP facility rooms (i.e., SPVD excavations) indicate mining-induced fracturing in the rock-salt floor material and in the underlying MB139 immediately beneath the excavations. Investigations of the long-term mechanical and fluid-flow behavior of MB139 and its potential impact on the WIPP underground facility are on-going; the following discussions and conclusions are considered preliminary.

Investigations by Borns (1985) indicate that subhorizontal fracturing, partially healed by halite and polyhalite, is characteristic of MB139 and predates the construction of the WIPP facility. The occurrence of partially healed fractures within the central part of MB139 is of importance to the fluid-flow characteristics and structural behavior of the unit. Pre-existing fractures within MB139 provide potential planes of weakness that could control or influence the mechanical response of the rock around the WIPP excavation. Underground experience at the WIPP indicates that these fractures open locally in response to excavation. Away from the influence of the WIPP excavation, the permeabilities of MB139 appear to be no greater than that of surrounding halites (Borns, 1985).

Mining-induced opening of fractures within MB139 may provide a potential pathway for gas or brine migration. This response to mining may require that damaged portions of MB139 be removed or grouted before seal emplacement.

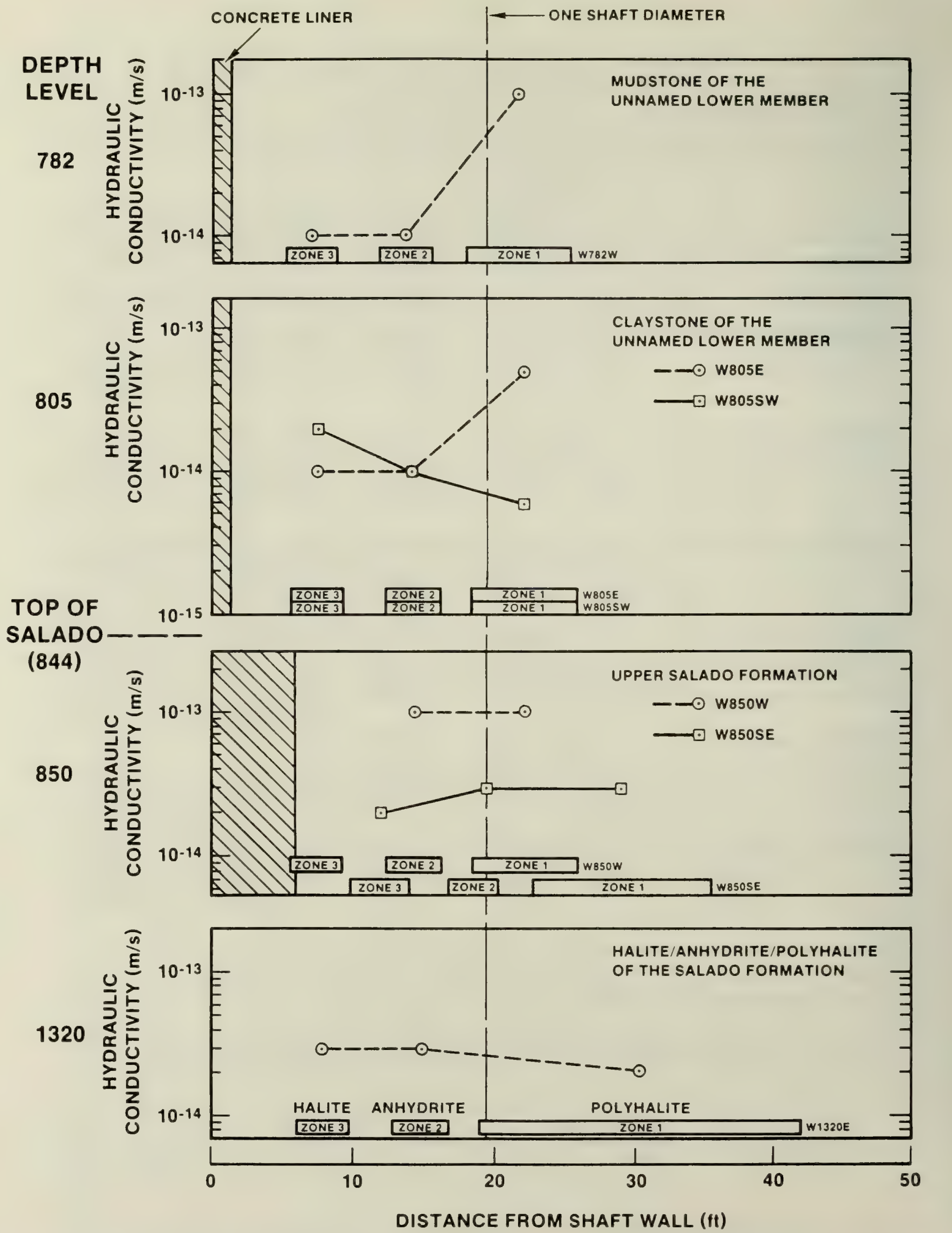
Table 4.6 Summary of the results of 1987 hydrologic testing in the WIPP waste-handling shaft[a]

Borehole	Lithology	Test Zone Depth Int. (Ft from Shaft Wall)	Pressure Pulse (psi)	Hydraulic Conductivity (m/s)	Formation Pressure (psi)
W782W	Silty mudstone	1) 18.6-26.0	113.3	1.0×10^{-13}	90
		2) 12.3-15.9	108.3	1.0×10^{-14}	140
		3) 5.4-9.5	99.4	1.0×10^{-14}	140
W805W	Silty claystone	1) 18.6-26.0	94.5	5.0×10^{-14}	225
		2) 12.3-15.9	105.1	1.0×10^{-14}	140
		3) 5.4-9.5	97.8	1.0×10^{-14}	110
W805SW	Silty claystone	1) 18.6-26.5	102.9	6.0×10^{-15}	275
		2) 12.3-15.9		1.0×10^{-15}[b]	90[b]
		3) 5.4-9.5	92.6	2.0×10^{-14}	70
W850W	Halite	1) 18.6-26.0	97.6	1.0×10^{-13}	40
		2) 12.3-15.9	116.5	1.0×10^{-13}	40
		3) 5.4-9.5	90.34	Not analyzable	--
W850SE	Halite	1) 23.2-36.0	103.5	3.0×10^{-14}	50
		2) 16.8-20.5	103.1	3.0×10^{-14}	30
		3) 10.0-14.1	100.7	2.0×10^{-14}	90
W1320E	Halite/ Anhydrite Polyhalite	1) 18.6-41.8	173.3	2.0×10^{-14}	550
		2) 12.3-15.9	52.6	3.0×10^{-14}	450
		3) 5.4-9.5	53.0	3.0×10^{-14}	100

---

[a] From Saulnier and Avis (1988)

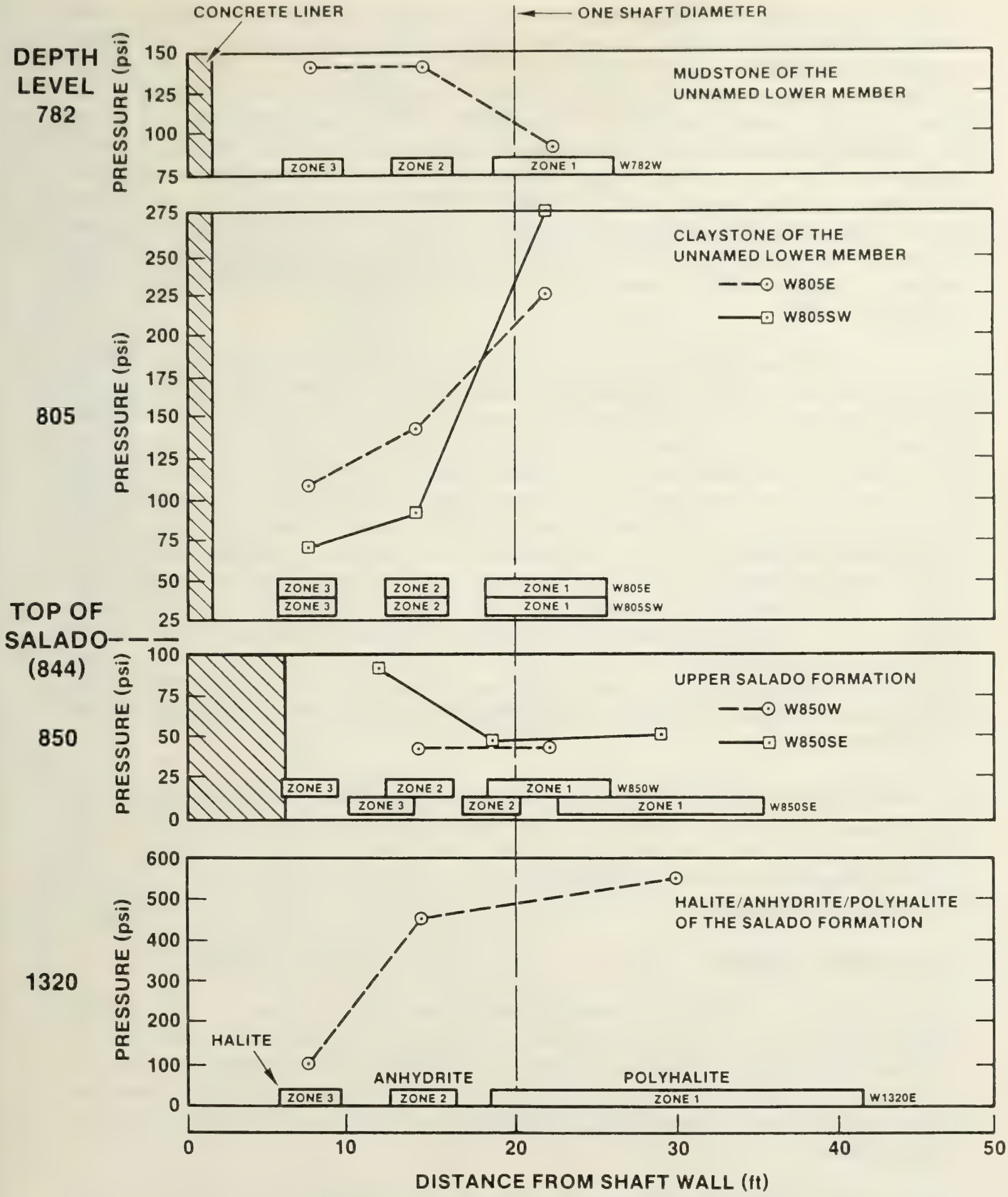
[b] Zone 2 analysis from pressure buildup after shut-in, August 28 to 31, 1987.



NOTE: DETERMINED IN 1987 TESTING IN THE WIPP WASTE HANDLING SHAFT.

REF: SAULNIER AND AVIS, 1988.

FIGURE 4.8
SUMMARY OF FORMATION CONDUCTIVITIES



NOTE: DETERMINED IN 1987 TESTING IN THE WIPP WASTE HANDLING SHAFT.

REF: SAULNIER AND AVIS, 1988.

FIGURE 4.9
SUMMARY OF FLUID FORMATION PRESSURES

4.3.2.5 Geochemical and Mineralogical Environment of the WIPP Facility Horizon. The Salado Formation is dominated by various evaporite salts. The dominant mineral being bedded salt (NaCl) of varying purity and accessory minerals. The major accessory minerals are anhydrite ($CaSO_4$), clays, polyhalite ($K_2MgCa_2(SO_4)_4 \bullet 2H_2O$), and gypsum ($CaSO_4 \bullet 2H_2O$) (Lappin, 1988; Stein, 1985; Bodine, 1978). Stein (1985) reports that, in the vicinity of the repository, authigenic quartz (SiO_2) and magnesite ($MgCO_3$) are also present as accessory minerals. The marker beds in the salt are described as anhydrite with seams of clay (Lappin, 1988). Bodine (1978) noted that the clays within the Salado Formation are enriched in magnesium and depleted in aluminum. The magnesium enrichment probably reflects the intimate contact of the clays with brines derived from evaporating sea water, which are relatively high in magnesium (Stein and Krumhansl, 1986).

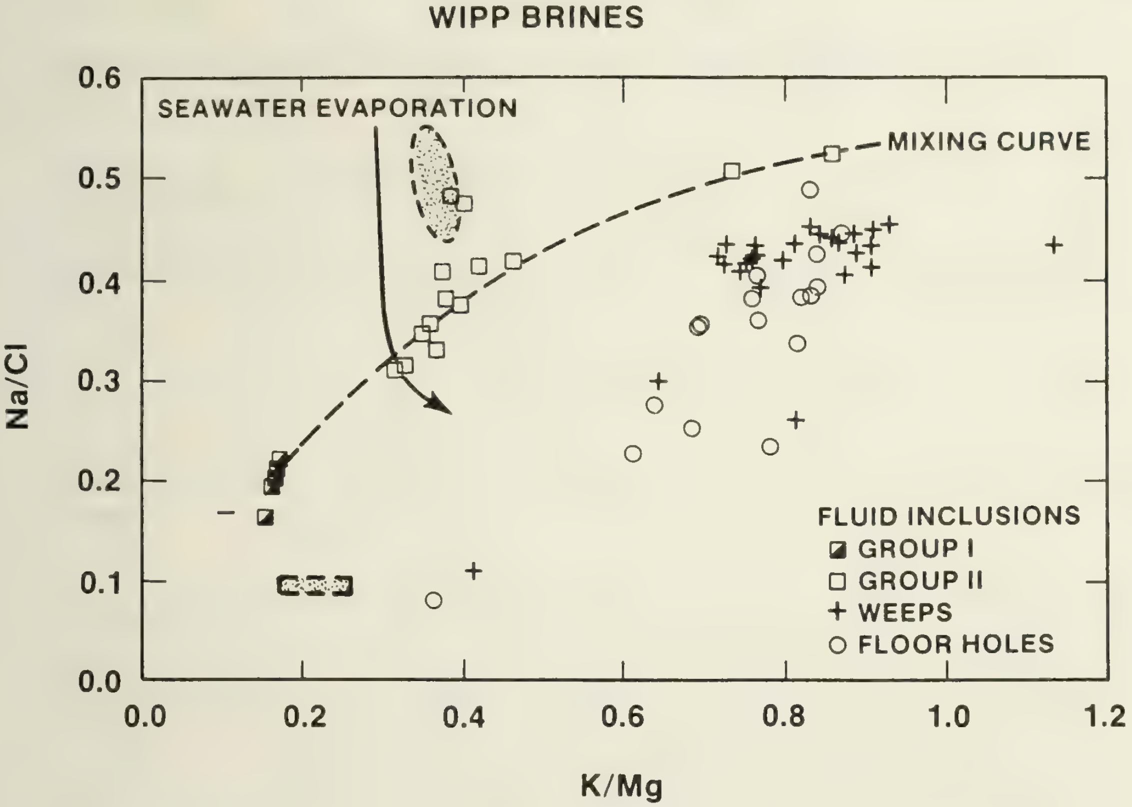
Stein and Krumhansl (1986) collected and analyzed liquids from two types of fluid inclusions as well as from seeps and floor holes within the WIPP drifts. Figure 4.10 is a plot of the ratios of sodium to chloride versus potassium to magnesium in samples of these four fluids. The lower portion of the figure shows variability of the fluids. The upper portion of the figure shows the effects of various phase transformations on brine composition. In summary, the fluid inclusions belong to a different chemical population than do the fluids emanating from the walls. It was concluded that much of the brine is completely immobilized within the salt and that the free liquid that emanates from the walls is present as a fluid film along intergranular boundaries (Stein and Krumhansl, 1986). This supports the discussion in Deal and Case (1987) and in Subsection 4.3.2.1. One of the distinguishing characteristics of these intergranular fluids is the increase in the potassium/magnesium ratio. The precipitation of either magnesite, ($MgCO_3$), or magnesium-rich clays from the intergranular fluids can cause this geochemical evolution. These mineral species are present as accessory minerals within the Salado Formation.

To develop a set of reference brine concentrations, Lappin et al. (1989) compiled and critically evaluated the present data from WIPP seeps and boreholes. Table 4.7 is a list of the concentrations of the major and minor components in Brine 2 (PAB 2). The critical evaluation consisted of discarding outlier values and analyses that indicated potential contamination.

4.3.3 **Rustler Formation**

Much effort during WIPP site characterization has been focused on the Culebra Dolomite Member of the Rustler Formation because the Culebra is the first laterally continuous hydrologic system above the Salado Formation, and it provides the most likely potential pathway for any release from the repository to the accessible environment. However, since 1983, characterization has also included other members of the formation.

At the time of the FEIS, three water-producing units were thought to exist within the Rustler. Currently, five water-bearing units have been identified within the Rustler: 1) the lower siltstone portion of the unnamed lower member of the Rustler and the Rustler-Salado contact, 2) the Culebra Dolomite, 3) the Tamarisk claystone, 4) the Magenta



NOTE: FROM FLUID INCLUSIONS AND MACROSCOPIC BRINE OCCURENCES IN THE WIPP FACILITY; EFFECTS OF INDIVIDUAL REACTIONS ON FLUID COMPOSITION ARE ALSO INDICATED.

REF: STEIN AND KRUMHANSL, 1986.

FIGURE 4.10
COMPOSITIONAL VARIABILITY OF SALADO FORMATION FLUIDS

TABLE 4.7 Geochemistry of PAB 2

Species	Average Concentration (millimoles per liter)
pH (standard units)	6.1
Alkalinity (pH 4.5)[a]	13.8 (as HCO_3^-)
Extended alkalinity (pH 2 to 3)[a]	15.7 (as HCO_3^-)
B^{3+}	148
Ca^{2+}	9
K^+	510
Mg^{2+}	1,000
Na^+	3,900
Br^-	148
Cl^-	6,020
SO_4^2	170
TDS (miligrams per liters)	3.78×10^5 (miligrams per liters)
Specific gravity	1.22

[a] Final pH after titration.

Dolomite, and 5) the Forty-Niner Claystone (Figure 4.11). These water-bearing units are separated by confining beds (units that inhibit water flow) of evaporite rocks (i.e., rock salt, halite, anhydrite, gypsum).

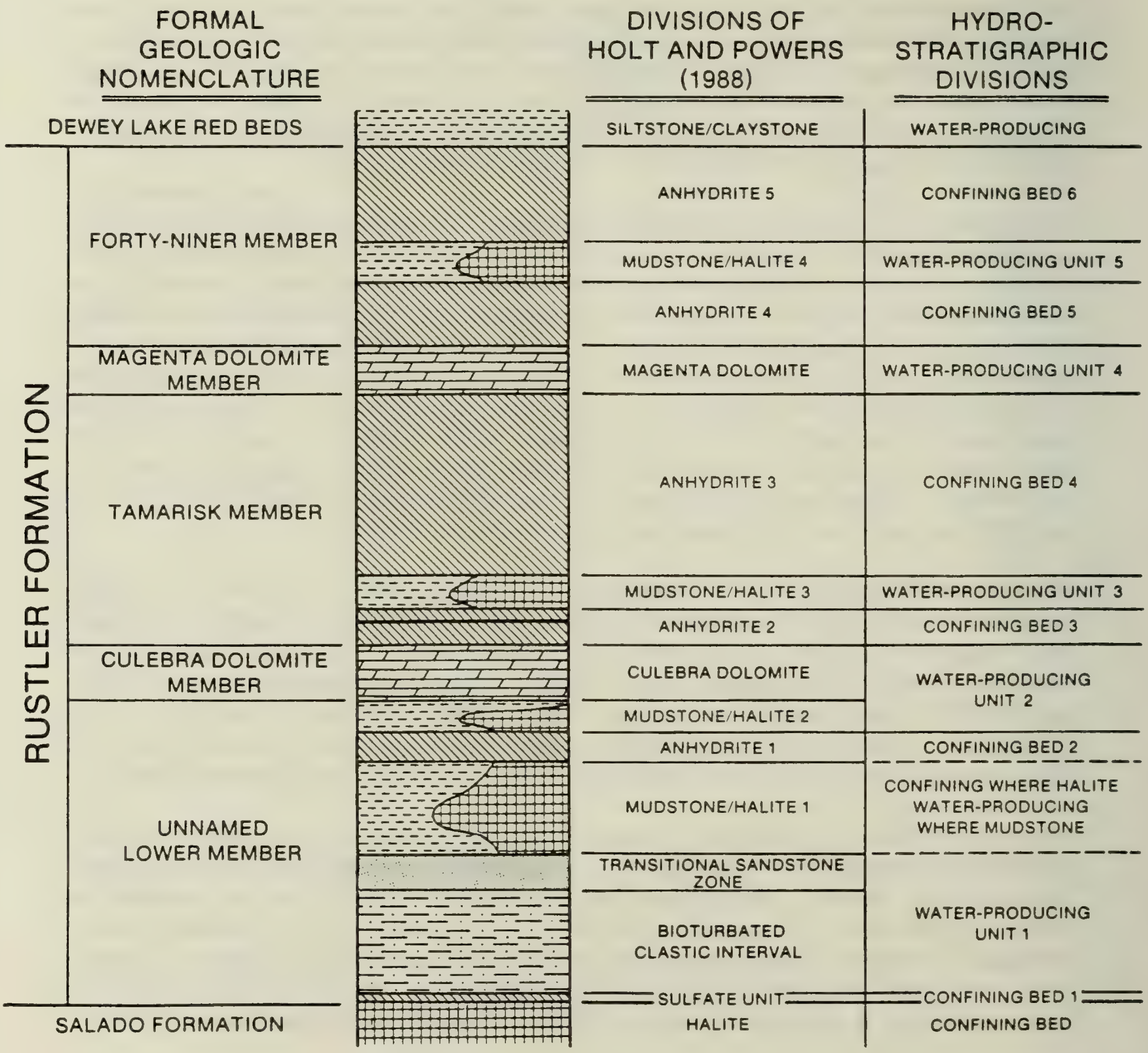
The potential for the dissolution of salts within the Rustler Formation has been identified. The concern has been that evaporite dissolution could play a major role in the potential breach of the WIPP underground facility. Nash Draw to the west of the WIPP, where the Rustler is devoid of rock salt, is an example of salt dissolution as compared to the abundant halite in the Forty-Niner, the Tamarisk, and the unnamed member to the east of the WIPP (Chaturvedi and Channell, 1985).

Two methods of dissolution have been identified: 1) strata-bound dissolution (i.e., dissolution parallel to bedding) and 2) localized dissolution from recharge. The variability of halite content and the associated thickness of the Rustler Formation has been thought to result from regional-scale, strata-bound dissolution. This has been based on the assumption that rock salt was deposited with uniform thickness over a large area. It has been assumed that the Nash Draw feature is due to the dissolution of Rustler salts over the past 600,000 years. The assumption that dissolution is the main cause of the variability in the salt content within the Rustler and the growth of Nash Draw have been viewed as conservative. Even with the above conservative assumptions, it does not appear feasible for salt dissolution to extend Nash Draw to the WIPP for many tens of thousands of years (Lappin, 1988).

The alternative method for the dissolution of the Rustler Formation is localized recharge. If localized recharge of unsaturated fluids occurred to a significant degree, local evaporite dissolution within the Rustler might result. The final result of such dissolution could be the generation of a "solution hole" hydrologic system similar to the hydrology of at least part of the Rustler Formation in Nash Draw. Where the Rustler Formation is exposed at the surface, it is characterized by the continuing formation of small caves and sinkholes in the anhydrites of the Forty-niner and Tamarisk Members.

The characterization of the Rustler Formation since the FEIS has provided considerable evidence regarding the potential for dissolution at the WIPP. Hydrologic measurements, including regional-scale pumping tests, have been used to evaluate the present distribution of hydraulic properties and relative head potentials (water pressures) within the Rustler at and near the WIPP. Water isotope studies have been used to estimate the relative importance of vertical fluid flow within the Rustler and Dewey Lake and the extent to which the Rustler flow system is in a transient state.

The results of these studies indicate that vertical recharge to the Rustler is not active at the WIPP. The results of regional-scale pumping tests in the Culebra Dolomite have not identified zones of high transmissivities, which would be characteristic of dissolution features (pumping-test results are discussed later in this section). Also, data on the isotopes present in the water (Lambert and Harvey, 1987) indicate that the water currently present in the Rustler originated from recharge that occurred during the last pluvial event (10,000 to 20,000 years before the present).



REF: LAPPIN et al., 1989.

FIGURE 4.11
HYDROSTRATIGRAPHIC COLUMN OF THE RUSTLER FORMATION IN THE VICINITY OF THE WIPP SITE

4.3.3.1 Hydrogeology of the Rustler Formation Water-Bearing Units.

Unnamed Lower Member and Rustler-Salado Contact. The unnamed lower member of the Rustler Formation consists of a layered sequence of clayey siltstone, gypsum/anhydrite, and rock salt. In and near the WIPP, the thickness of the unnamed lower member ranges from 79 ft (at ERDA-6) to 151 ft (at P-18). The lower siltstone unit of the unnamed member [the transition zone and the biologically disturbed clastic interval of Holt and Powers (1988)] can be considered to be the lowermost Rustler water-producing zone, while the overlying rock salt and anhydrite/gypsum units act as another confining bed. The top unit of the unnamed member is composed of siltstone, mudstone, and claystone. At some locations south and east of the WIPP site, such as at P-18, this unit also contains rock salt (Holt and Powers, 1988).

Typically the transmissivities of the water-producing portion of the unit vary from 10^{-11} to 10^{-9} m^2/s. Where the dissolution of the upper Salado Formation has occurred, the transmissivities tend to be at the higher end of the range. Under these conditions, the brine-bearing residue of the upper Salado may be hydraulically continuous with the siltstone of the unnamed member.

To the west and southwest of the WIPP site, where rock salt is absent from the upper Salado Formation and the lower Rustler Formation, a more transmissive zone exists in the residue of the upper Salado Formation at the contact with the Rustler Formation. The brecciation (breaking up into angular fragments) of the unnamed lower member has been observed in Nash Draw where the upper Salado Formation has been dissolved (Holt and Powers, 1988), but the degree to which this brecciation may have caused enhanced transmissivity or decreased the effectiveness of the confining beds of the unnamed member is not clear from the available evidence. Where dissolution of the upper Salado Formation has not occurred, no significant permeability is associated with the upper Salado Formation and its contact with the Rustler Formation, and the lower siltstone provides the only water-producing unit in the lower Rustler Formation.

Very few measurements have been made of the stabilized water level or fluid pressure of the unnamed lower member of the Rustler Formation. Water levels take months to years to stabilize in wells completed saturated sediments of in extremely low transmissivity, such as those that make up the unnamed member. Most of the borings testing the lower Rustler Formation and/or upper Salado residuum were temporary measurement points and did not remain open at that zone long enough to reach hydraulic equilibrium (i.e., water-pressure conditions returning to static conditions after drilling). Hydraulic head data are believed to be reliable only at those wells where transmissivities in the unit exceed 6×10^{-10} m^2/s.

Because the highly variable salinity of the water in the Rustler and Salado Formations affects the density of the waters and the resulting hydraulic head, (water level measurement for determining pressure), the hydraulic-head data must be corrected to a common density (in this case, freshwater) to determine groundwater flow patterns. The corrected data indicate that flow through the low-transmissivity section of the Rustler-Salado contact is generally westerly or southwesterly across the WIPP site toward the sink represented by the higher transmissivities in Nash Draw. The flow within Nash Draw appears to be generally southwesterly toward Malaga Bend on the Pecos River.

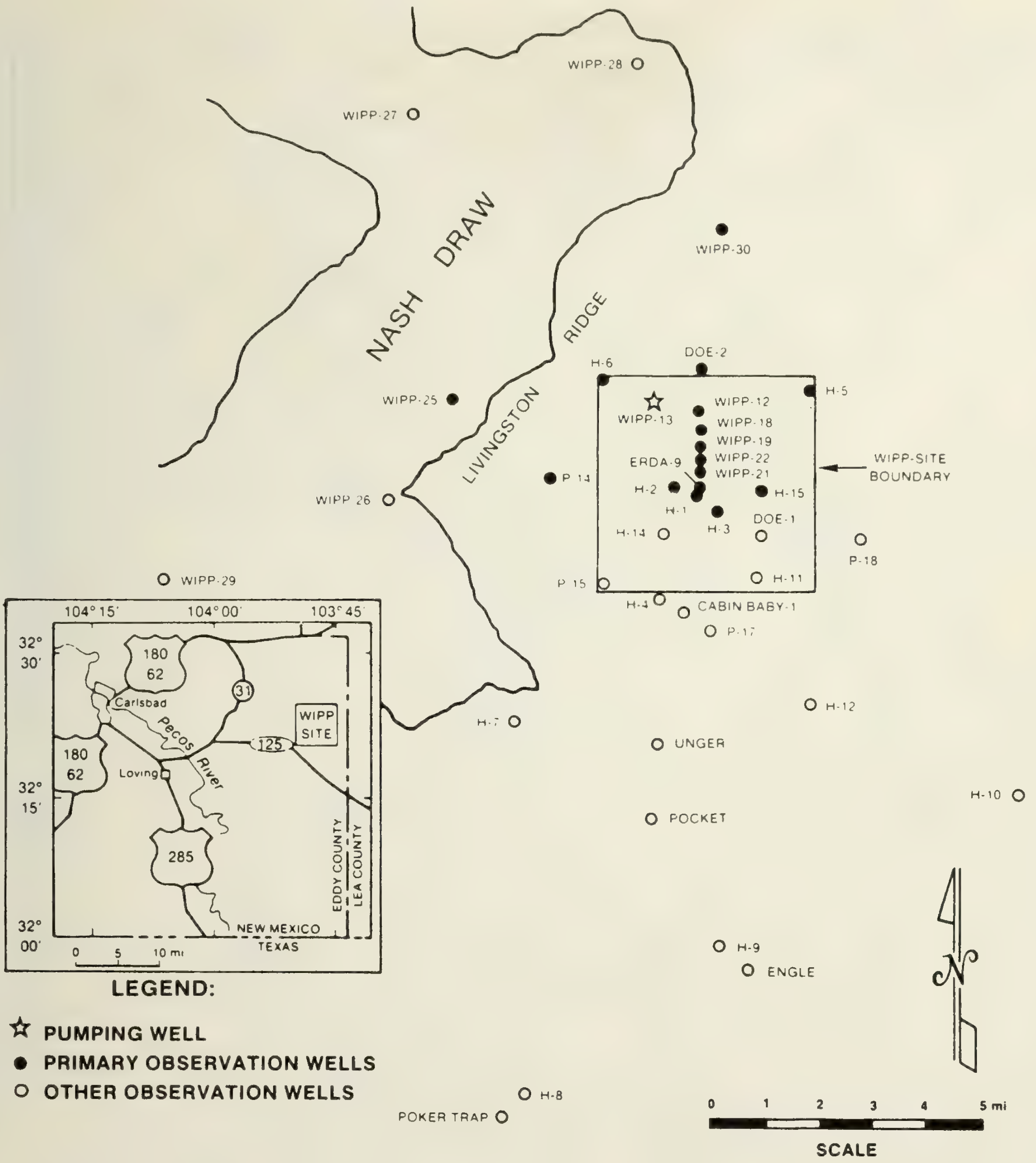
Culebra Dolomite. The Culebra Dolomite Member of the Rustler Formation is a finely crystalline, locally clayey, sandy, vuggy (containing small cavities) dolomite ranging in thickness from 23 ft (at DOE-1 and other locations) to 46 ft (at H-7) in the vicinity of the WIPP. Of the hydrostatigraphic units present within the Rustler Formation, the Culebra has the greatest potential of providing a groundwater-transport pathway to the accessible environment. Accordingly, much attention has been devoted to understanding the hydrogeologic and hydraulic properties of the Culebra.

The Culebra is underlain by a siltstone/mudstone/claystone unit of the unnamed lower member and overlain by an anhydrite unit of the Tamarisk Member. These units provide confining hydraulic boundaries for the Culebra. During the WIPP site characterization, regional hydraulic properties have been investigated by multipad interference testing of the Culebra Dolomite. This test is conducted by pumping a test well over a long time. (e.g., for a month or longer), while surrounding holes are used to observe response to stress in the Culebra Dolomite over an area of several square miles.

Three multipad interference tests have been conducted to date. These tests were conducted in the Culebra Dolomite and were centered at hydropad H-3, hole WIPP-13, and hydropad H-11. The locations of WIPP-13 and the wells used for observation are shown in Figure 4.12. The locations of the H-3 multipad and the observation wells for this test are shown in Figure 4.13. Interpretation of the H-11 multipad test is not yet complete.

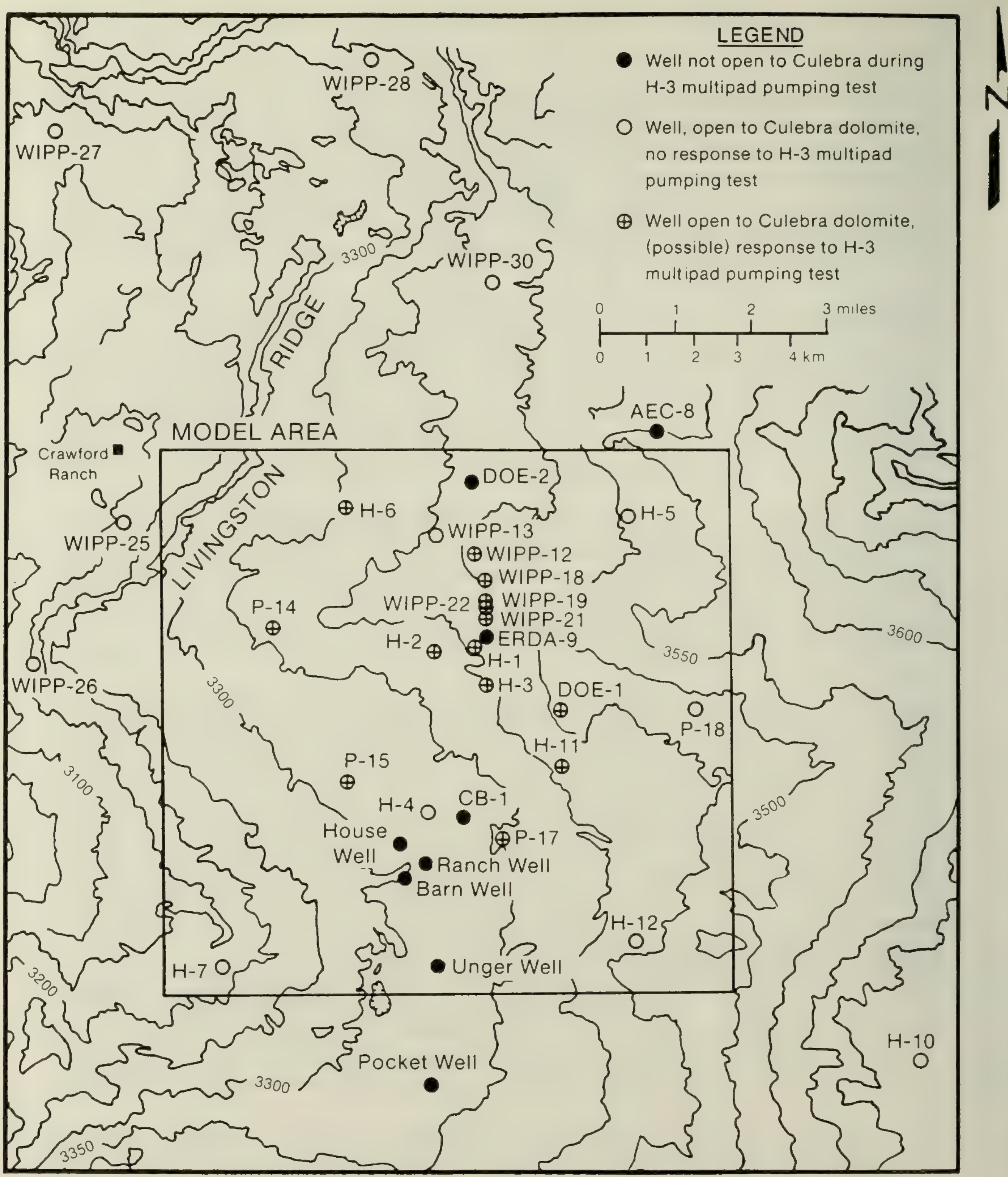
The pumping phase of the H-3 multipad interference test took place between October 15, 1985, and December 16, 1985. The collection of recovery data (the period when conditions return to normal) extended to April 16, 1986. The Culebra potentiometric surface (water-pressure levels) at the WIPP site is and has been affected by a small continuous discharge (0.5 to 1 gal/min per shaft) into the WIPP shafts (Haug et al., 1987). Thus, delineation of a potentiometric surface undisturbed by WIPP activities is difficult. LaVenue et al. (1988) performed a thorough review of Culebra water-level data, fluid-density data, and WIPP-related hydraulic stresses and derived estimates of the undisturbed freshwater heads at 31 wells. These estimates are shown contoured on Figure 4.14. The freshwater-head contours indicate a southerly flow direction across the WIPP site, a southwesterly flow direction down Nash Draw, and an area of low gradients with apparent westerly flow south of the WIPP site. Lappin et al. (1989) report that flow directions in this southern area of low hydraulic gradients are difficult to define reliably because variations in fluid density in this part of the Culebra may be as important as head differences in determining flow directions.

Tamarisk Claystone. The Tamarisk Member of the Rustler Formation is composed of two anhydrite and/or gypsum units with a silty-mudstone interbed in the lower half of the member (Figure 4.11). The anhydrite/gypsum units act as confining beds, while the mudstone is the least productive of the Rustler water-producing units. Less is known about the hydraulic properties of the Tamarisk than about those of the other Rustler members. Hydraulic tests of the Tamarisk Claystone have been attempted at only four locations: H-3b3 (unpublished field notes, 1984), DOE-2 (Beauheim, 1986), H-14 (Beauheim, 1987a), and H-16 (Beauheim, 1987a). Testing at all four locations was



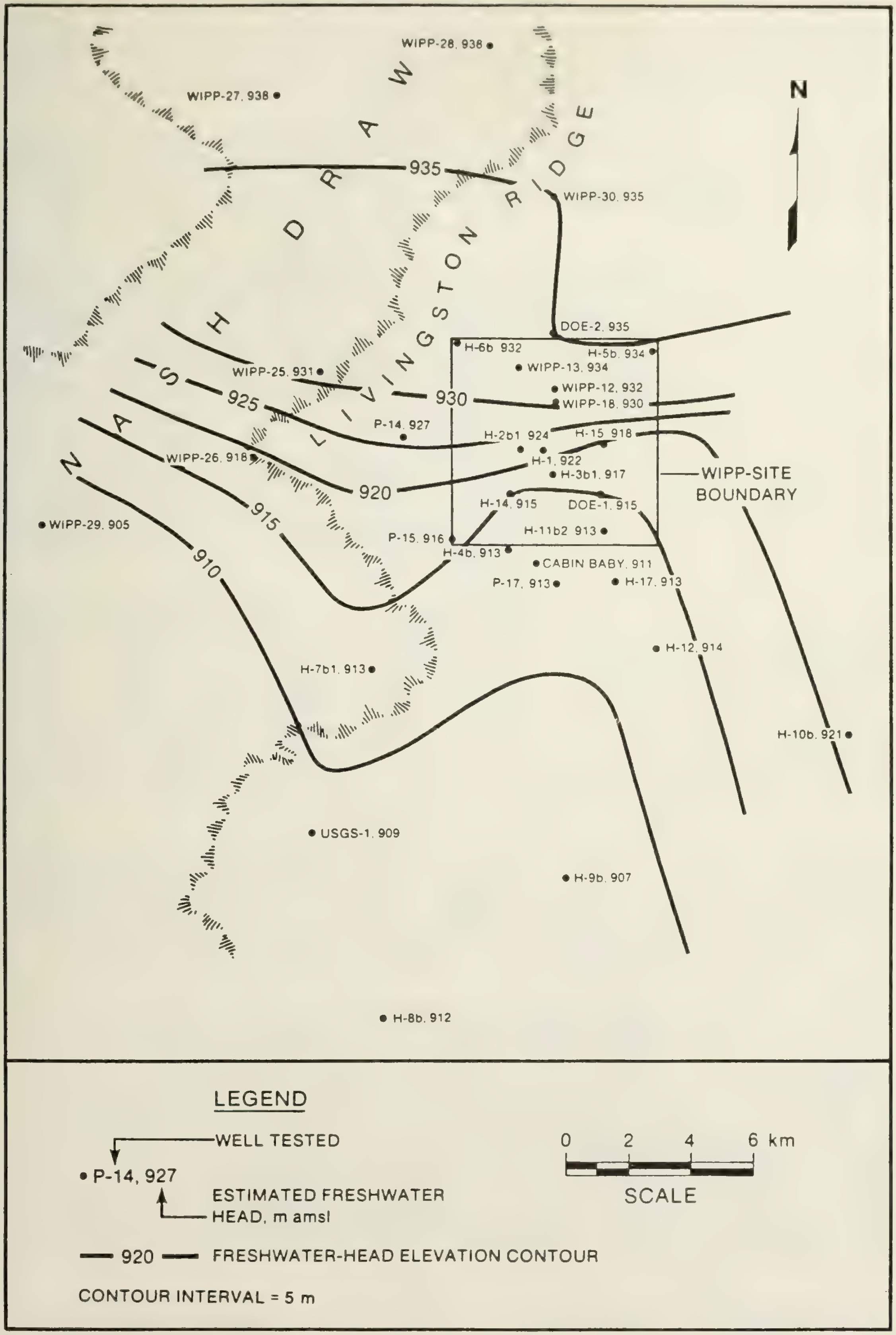
REF: BEAUHEIM, 1987c.

FIGURE 4.12
PUMPING AND OBSERVATION WELLS FOR THE WIPP-13 MULTIPAD INTERFERENCE TEST



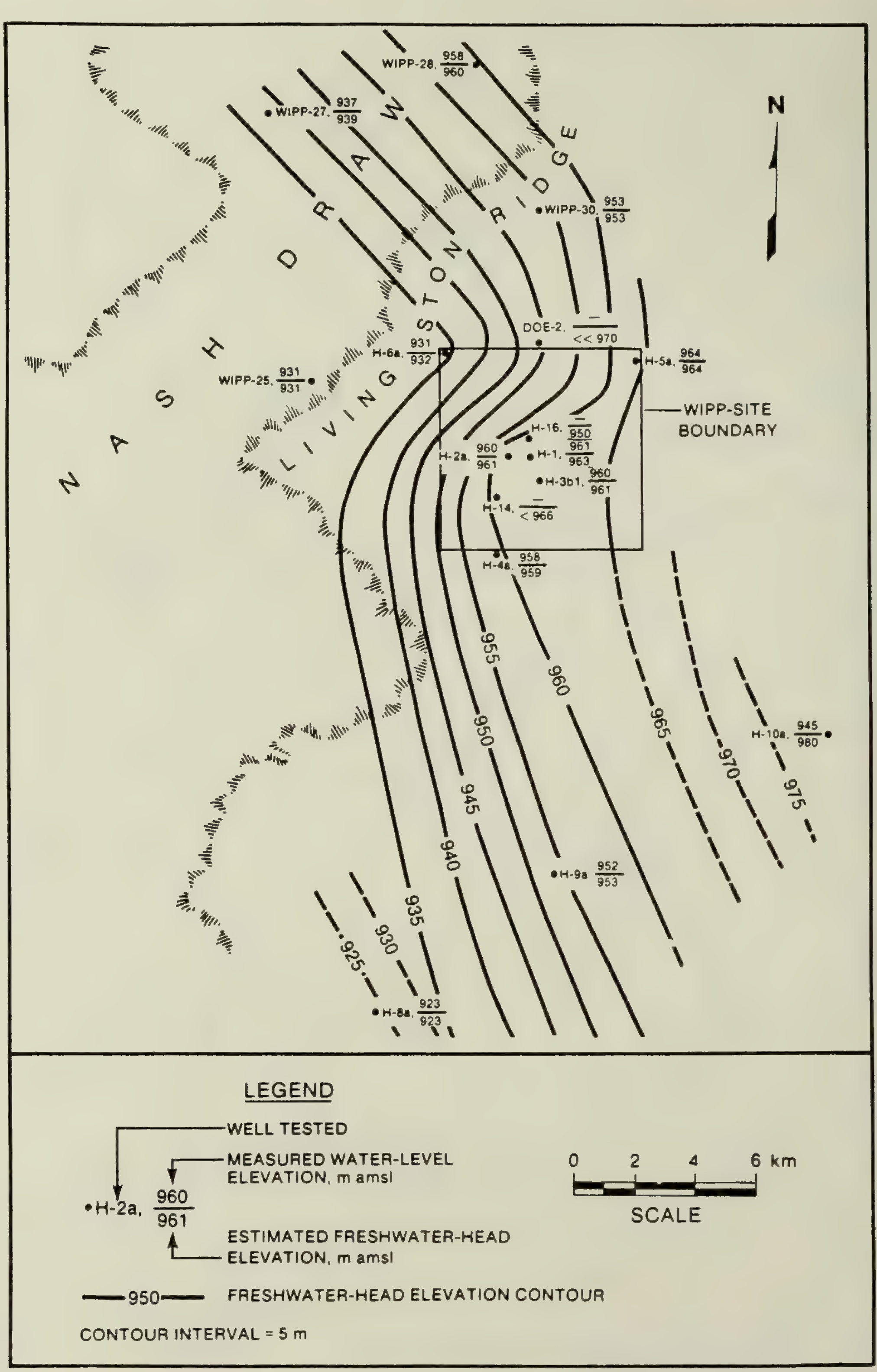
REF: HAUG et al., 1987.

FIGURE 4.13
PUMPING AND OBSERVATION WELLS FOR
THE H–3 MULTIPAD INTERFERENCE TEST



REF: LAPPIN et al., 1989.

FIGURE 4.14
ESTIMATED FRESHWATER HEADS OF THE CULEBRA DOLOMITE MEMBER



REF: LAPPIN et al., 1989.

FIGURE 4.15
WATER LEVELS AND ESTIMATED FRESHWATER HEADS
IN THE MAGENTA DOLOMITE MEMBER

inconclusive, apparently because the transmissivities were too low to measure over a period of several days. Similar tests performed successfully on the unnamed lower member at H-16 (Beauheim, 1987a) indicate that the transmissivity of the Tamarisk claystone is likely 10^{-11} m^2/s or less in the vicinity of the WIPP.

Magenta Dolomite. The Magenta Dolomite Member (Magenta) of the Rustler Formation is a sandy dolomite containing gypsum. It ranges in thickness from 16 ft (at WIPP-27) to 30 ft (at H-9) in the vicinity of the WIPP. The Magenta is absent at WIPP-29 and is unsaturated at H-7a and WIPP-26 (Mercer, 1983).

Hydraulic tests have been performed on the Magenta dolomite at 16 locations (Mercer, 1983; Beauheim, 1986, 1987a). Most of the transmissivity values are less than or equal to 10^{-7} m^2/s. Relatively high values of transmissivity, 3×10^{-7} and 1×10^{-6} m^2/s, are found at H-6a and H-9a, respectively. Rock salt is not present in the Rustler Formation at either of these two locations, and transmissivities measured within the Culebra are also high at both locations. The two highest values of Magenta transmissivity, 4×10^{-4} and 6×10^{-5} m^2/s, are found in Nash Draw at WIPP-25 and WIPP-27, respectively, where dissolution in the upper Salado has caused the collapse and fracturing of the overlying Rustler. Dissolution in the upper Salado has apparently not affected the Magenta at all locations where the Salado has dissolved; for example, the transmissivity of the Magenta is very low at H-8 and could not be measured at WIPP-28.

Stabilized hydraulic-head data were measured in the Magenta between 1979 and 1981 (Richey, 1987b). Density-corrected hydraulic-head estimates calculated from specific-gravity or fluid-density data presented by Mercer et al. (1987), Dennehy and Mercer (1982), Mercer (1983), Lambert and Robinson (1984), Richey (1986), and Richey (1987a) and measured heads are shown in Figure 4.15. The contours based on corrected data indicate a generally westward flow direction across the WIPP and a southwesterly flow direction within the Magenta in the northern portion of the Nash Draw.

Forty-niner Member. The Forty-niner Member of the Rustler Formation is composed of two anhydrite and/or gypsum units separated by a silty mudstone interbed. The anhydrite/gypsum units act as confining beds to the saturated mudstone interbed. In the vicinity of the WIPP, the thickness of the Forty-niner ranges from 23 ft at WIPP-27 to 75 ft at P-18. The Forty-niner is entirely absent at WIPP-29 (Mercer, 1983).

The mudstone interbed of the Forty-niner has been hydraulically tested only at three locations: DOE-2, H-14, and H-16 (Beauheim, 1986; 1987a). At these locations, the thickness of the interbed ranges from 10 to 16 ft. The transmissivities reported for the mudstone interbed at these locations range from 10^{-9} to 10^{-7} m^2/s. Although no direct measurements have been made, it is assumed that transmissivities may be higher west of the WIPP site in Nash Draw, as is the case with the other Rustler members. Measurements of the hydraulic head of the Forty-niner mudstone have been made at wells H-3d, H-14, H-16, and DOE-2 (Beauheim, 1987a). These data infer a flow system that is southwesterly, which is generally consistent with other members in the Rustler Formation.

Hydraulic-Head Relations. The hydraulic-head distributions shown for the unnamed lower member of the Rustler Formation and the Rustler/Salado contact, the Magenta Dolomite Member, and the Forty-niner mudstone all indicate westerly to southwesterly components to the groundwater flow in these units. Flow in the generally more transmissive Culebra appears to be largely southerly. Steady-state flow conditions would indicate that recharge to the Rustler Formation is to the east or northeast of the WIPP. However, to the east of the WIPP, the depth at which the Rustler is located increases, the transmissivities of the water-producing units decrease, and the thickness and effectiveness of confining beds increase. All of these factors argue against the existence of recharge areas to the east.

Data on the isotopes in the Rustler groundwaters and hydraulic-head distributions in the Rustler Formation (Lambert and Harvey, 1987) indicate that the flow systems are not at steady state, but are instead in a transient state following a major recharge event during the latest pluvial period. The Rustler Formation was recharged, perhaps from the present vicinity of Nash Draw, during a pluvial period on the order of 10,000 to 20,000 years before the present. Following the climatic change to the current semi-arid conditions, the Rustler began to drain to the west or southwest. The Culebra, the most transmissive of the Rustler water-producing units, apparently has drained more quickly than the other units, resulting in its present-day flow direction. Numerical simulation (Lappin et al., 1989) of the recharge-discharge scenario proposed by Lambert and Harvey (1987) indicates that the current distribution of heads is a plausible result of more than 10,000 years of drainage from the Rustler.

4.3.3.2 Hydrologic Testing of the Rustler Formation. The Rustler Formation hydrogeologic data base at the time of the FEIS consisted of data derived from testing at eight locations (Cooper and Glanzman, 1971; and Mercer and Orr, 1979). WIPP-site characterization of the Rustler Formation that has taken place since the FEIS has included testing at 33 additional well sites. Hydrologic testing of the Rustler Formation has occurred at three geometric scales: 1) local or point tests in single holes; 2) multiple-well hydropad (three wells at 98.4-ft spacing in the form of an equilateral triangle) tests; and 3) regional-scale testing using multiple hydropads.

Single-hole Tests. Single-hole hydrologic testing has provided 1) local transmissivity values for all members of the Rustler Formation except the Tamarisk, with focus on the Culebra; 2) indications of local fracturing and well-bore damage in the Culebra; 3) relative head data within the Rustler; and 4) some indication of the hydraulic properties and degree of saturation in the Dewey Lake Red Beds (Lappin, 1988). Single-hole testing methods are discussed by Beauheim (1987b). Tests were conducted by means of pumping, drillstem, slug-injection, slug-withdrawal, or pressure-pulse methods. Results of the single-well tests discussed in Barr et al., (1983), Haug et al., (1987), LaVenue et al., (1988), and Beauheim (1986, 1987b) are presented in Tables 4.8 and 4.9. Single-well tests provide only a localized measure of hydraulic properties at the point of the test. They do not indicate the extent to which transmissivity values or fracturing effects can be extrapolated laterally.

Single-Pad, Multiple-Well Hydropad Tests. In order to provide a more laterally extensive understanding of the Culebra hydraulic properties, tests were conducted on a hydropad scale. During testing, a single well is pumped and the other two wells provide observation points.

TABLE 4.8 Transmissivity data bases used in the numerical modeling of the Culebra Dolomite by Barr et al., (1983) Haug et al., (1987) and LaVenue et al., (1988)

	Transmissivity (ft^2/day)			
Well	Barr et al., (1983)	Haug et al., (1987)	LaVenue et al., (1988)	Average transmissivity (m^2/s)
H-1	0.07	0.07	0.8	8.60×10^{-7}
H-2	0.4	0.56	0.52	5.59×10^{-7}
H-3	19	3.7	2.3	2.47×10^{-6}
H-4	0.9	1.1	0.95	1.02×10^{-6}
H-5	0.2	0.16	0.14	1.51×10^{-7}
H-6	73	74	74	7.96×19^{-5}
H-7	>1000	1120	1030	1.11×10^{-3}
H-8	16	6.7	8.2	8.82×10^{-6}
H-9	230	170	160	1.72×10^{-4}
H-10	0.07	0.07	0.07	7.53×10^{-8}
H-11	--	10	26	2.80×10^{-5}
H-12	--	0.04	0.18	1.94×10^{-7}
H-14	--	--	0.31	3.33×10^{-7}
H-15	--	--	0.12	1.29×10^{-7}
H-16	--	--	0.7	7.53×10^{-7}
H-17	--	--	0.2	2.15×10^{-7}
H-18	--	--	--	--
WIPP-12	--	--	0.03	3.23×10^{-8}
WIPP-13	--	--	69	7.42×10^{-5}
WIPP-18	--	--	0.3	3.23×10^{-7}
WIPP-19	--	--	0.6	6.45×10^{-7}
WIPP-21	--	--	0.25	2.69×10^{-7}
WIPP-22	--	--	0.37	3.98×10^{-7}
WIPP-25	270	270	270	2.90×10^{-4}
WIPP-26	1250	1250	1250	1.34×10^{-3}
WIPP-27	650	650	650	6.99×10^{-4}
WIPP-28	18	18	18	1.94×10^{-5}
WIPP-29	1000	1000	1000	1.08×10^{-3}
WIPP-30	0.3	0.3	0.3	3.22×10^{-7}
P-14	140	233	214	2.30×10^{-4}
P-15	0.07	0.08	0.09	9.68×10^{-8}
P-17	1	1.7	1.3	1.40×10^{-6}
P-18	0.001	0.002	0.002	2.15×10^{-9}
DOE-1	--	33	11	1.18×10^{-6}
DOE-2	--	36	89	9.57×10^{-6}
ERDA-9	--	--	0.47	5.06×10^{-7}
CABIN BABY-1	--	--	0.28	3.01×10^{-7}
ENGLE	--	--	43	4.62×10^{-5}
USGS-1	515	515	515	5.54×10^{-4}
	21 values	25 values	38 values	38 values

TABLE 4.9 Detailed summary of the results of recent single-well tests in the Culebra Dolomite (Beauheim, 1987b)

Well	Culebra interval m (ft)	Interval tested m (ft)^b	Test type	Transmissivity	
				ft^2/day	m^2/s
H-1	206-213.1 (676-699)	205.7-214.3 (675-703)	Slug 1	1.0	1.1×10^{-6}
			Slug 2	0.83	8.9×10^{-7}
			Slug 3	0.83	8.9×10^{-7}
			Slug 4	0.83	8.9×10^{-7}
H-4c	149.4-157.3 (409-516)	150.6-158.5 (494-520)	Slug	0.65	7.0×10^{-7}
H-8b	179.2-187.1 (588-614)	175.0-190.2 (574-624)	Pumping	8.2	8.8×10^{-6}
H-12	250.9-259.1 (823-850)	249.9-271.3 (820-890)	Slug	0.18	1.9×10^{-7}
H-14	155.1-174.3 (545-572)	162.5-167.9 (533-550.7)	Drillstem	0.096	1.0×10^{-7}
			Drillstem	0.10	1.1×10^{-7}
			Drillstem	0.10	1.1×10^{-7}
H-14	166.1-174.3 (545-572)	162.5-175.0 (533-574)	Drillstem	0.30	3.2×10^{-7}
			Drillstem	0.31	3.3×10^{-7}
			Slug	0.30	3.2×10^{-7}
H-15	262.4-269.1 (861-883)	260.0-271.3 (853-890)	Drillstem	0.15	1.6×10^{-7}
			Drillstem	0.15	1.6×10^{-7}
			Slug	0.10	1.1×10^{-7}
H-16	213.4-221.0 (700-725)	212.4-223.7 (697-734)	Drillstem	0.85	9.1×10^{-7}
			Drillstem	0.85	9.1×10^{-7}
			Slug	0.69	4.7×10^{-7}
H-17	215.2-222.8 (706-731)	214.3-224.0 (703-735)	Drillstem	0.21	2.3×10^{-7}
			Drillstem	0.22	2.4×10^{-7}
			Slug	0.22	2.4×10^{-7}
H-18	210.3-217.3 (690-713)	208.8-217.6 (685-714)	Drillstem	2.2	2.4×10^{-6}
			Drillstem	2.2	2.4×10^{-6}
			Slug	1.7	1.8×10^{-6}
WIPP-12	246.9-254.5 (810-835)	248.4-256.0 (815-840)	Slug 1	0.10	1.1×10^{-7}
			Slug 2	0.097	1.0×10^{-7}

TABLE 4.9 Concluded

Well	Culebra interval m (ft)	Interval tested m (ft)[b]	Test Type	Transmissivity	
				ft^2/day	m^2/s
WIPP-18	239.9-246.3	239.0-245.7			
	(787-808)	(784-806)	Slug	0.30	3.2×10^{-7}
WIPP-19	230.4-237.4	229.8-237.7			
	(756-779)	(754-780)	Slug	0.60	6.5×10^{-7}
WIPP-21	222.2-229.5	221.6-228.9			
	(729-753)	727-751)	Slug	0.25	2.7×10^{-7}
WIPP-22	226.2-232.9	228.0-234.7			
	(742-764)	(748-770)	Slug	0.37	4.0×10^{-7}
WIPP-30	192.3-199.0	191.7-199.6			
	(631-653)	(629-655)	Slug 1	0.18	1.9×10^{-7}
			Slug 2	0.17	1.8×10^{-7}
P-15	125.9-132.6	125.0-133.5			
	(413-435)	(410-438)	Slug 1	0.090	9.7×10^{-8}
			Slug 2	0.092	9.9×10^{-8}
P-17	170.1-177.7	170.1-178.6			
	(558-583)	(558-586)	Slug 1	1.0	1.1×10^{-6}
			Slug 2	1.0	1.1×10^{-6}
P-18	277.1-285.9	277.1-286.5			
	(909-938)	(909-940)	Slug		$4 \times 10^{-3}/7 \times 10^{-5}$
ERDA-9	214.6-221.6	214.9-221.9			
	(704-727)	(705-728)	Slug 1	0.45	4.8×10^{-7}
			Slug 2	0.47	5.1×10^{-7}
Cabin	153.3-161.2	153.3-161.2			
Baby-1	(503-539)	(503-529)	Slug 1	0.28	3.0×10^{-7}
			Slug 2	0.28	3.0×10^{-7}
DOE-1	250.2-256.9	249.9-256.9			
	(821-843)	(820-843)	Pumping and		
			drawdown	28	3.0×10^{-5}
			recovery	11	1.2×10^{-5}
Engle	200.0-207.6	197.5-208.2			
	(659-681)	(648-683)	Pumping	43	4.6×10^{-5}

---

[a] Slightly modified from Table 5-3 of Beauheim (1987b).

[b] Actual intervals open to the wells.

Single-hydropad tests have been completed at the H-2, H-3, H-4, H-5, H-6, H-7, H-9, and H-11 hydropads. The locations of these hydropads and the wells used as observation points for the large-scale multipad interference tests are shown in Figure 4.16. Detailed evaluations have been completed only for the tests conducted at H-3 and H-11. Test-interpretation methods and details of analysis are discussed by Saulnier (1987), and Beauheim (1987a) and the results are summarized by Lappin (1988) and in Table 4-10. The interpretation of the test data made use of a dual-porosity approach, that is, a method that takes into account both the primary matrix porosity and the secondary porosity created by fracturing.

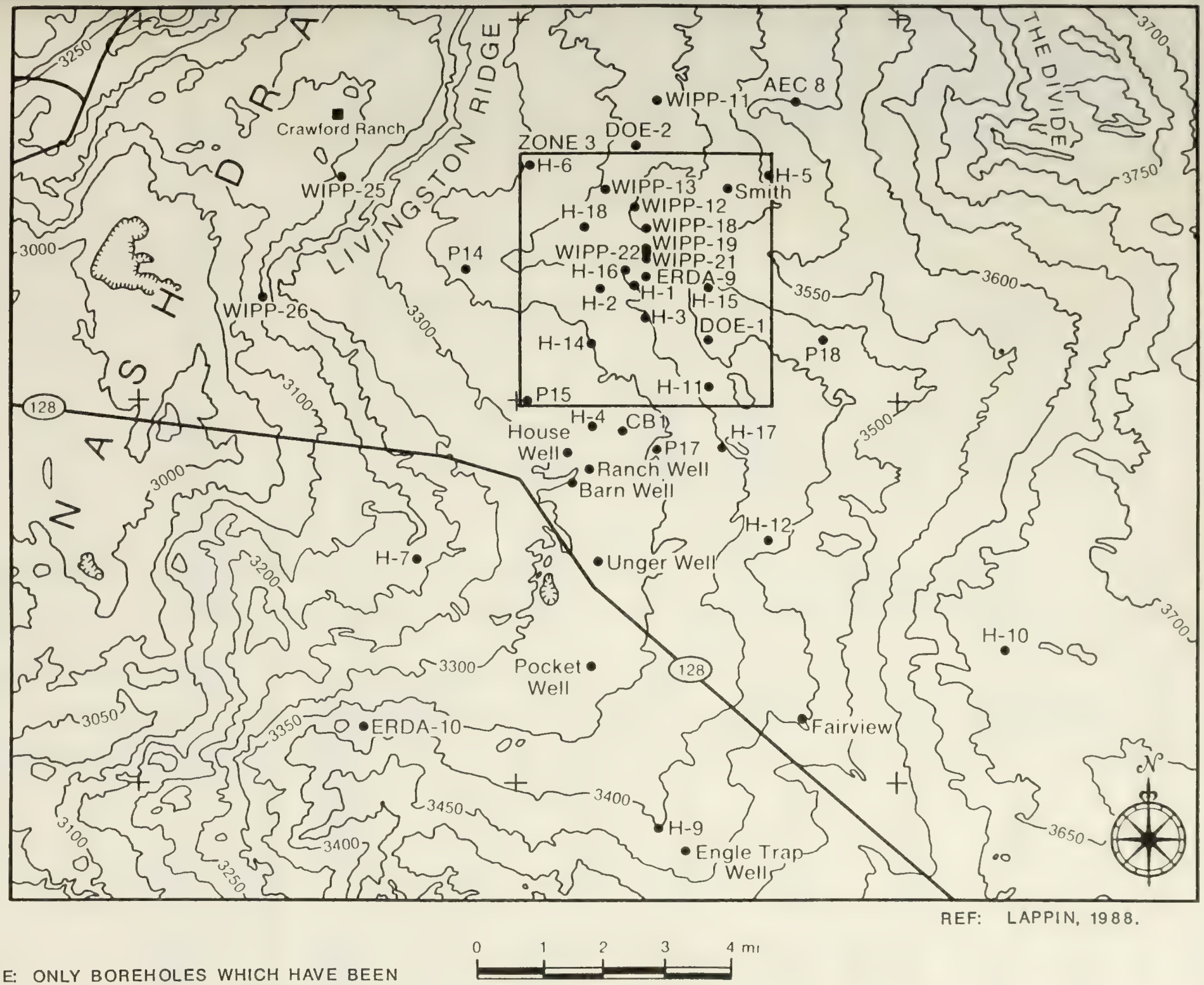
Multipad Interference Tests. The results of the hydropad tests, while providing valuable information on the hydraulic characteristics of the Culebra, do not provide an understanding of the Culebra hydraulic characteristics integrated over a large scale (several square miles). The regional effects of fracturing and whether the hydrologic system can regionally be treated as a porous medium for the purposes of transport modeling could be tested only by large-scale-system hydraulic-stress investigations. Such investigations use multipad interference tests.

Three multipad interference tests have been conducted to date. These tests were conducted in the Culebra Dolomite and were centered at hydropad H-3, hole WIPP-13, and hydropad H-11.

The locations of the H-3 multipad and the observation well are shown in Figure 4.13. The pumping phase of the H-3 test took place between October 15, 1985, and December 16, 1985. The collection of recovery data extended to April 16, 1986. Evaluation of the test data include the use of analytical methods (Beauheim, 1987a) and numerical simulations (Haug et al., 1987).

The results of the analytical evaluations are presented in Table 4.11. Because of the rapid response to pumping stress at observation wells DOE-1 and H-11b1 and the relatively high calculated transmissivities (approaching 10^{-5} m^2/s), Beauheim concluded that there is a preferential connection between the H-3 pad and the southeastern portion of the WIPP site. Tomasko and Jensen (1987) noted a linear relationship of drawdown versus the square root of time between DOE-1, H-11b1, and H-3b2. This provides a strong indication of linear flow (rather than radial flow) suggesting a zone with higher a transmissivity bounded by less permeable materials.

An analytical approach to the evaluation of regional-scale hydraulic properties in a system as complex as the Culebra has significant limitations. Haug et al., (1987) applied the numerical code SWIFT II (Reeves et al., 1986a; and Reeves et al., 1986b) to the evaluation of regional-scale hydraulic testing of the Culebra. The numerical approach takes into consideration: 1) complex patterns of regional flow, i.e., interpolation of hydraulic parameters between measurement points; 2) variable flow densities; and 3) leakage into or out of the Culebra.



REF: LAPPIN, 1988.

NOTE: ONLY BOREHOLES WHICH HAVE BEEN HYDROLOGICALLY TESTED ARE INCLUDED.

FIGURE 4.16
BOREHOLES AT AND NEAR THE WIPP SITE

Table 4.10 Summary of the result of single-pad interference tests in the Culebra Dolomite at the H-3 and H-11 hydropads.[a]

Well[b]	Transmissivity (m^2/s)	Skin factor	Storativity	Storativity ratio (ω)	Flow ratio (λ)
H-3[c]					
H-3b3 (1984, pump)	3.1×10^{-6}	-7.8	-----	0.07	-----
H-3b1	3.2×10^{-6}	-7.3	-----	0.25	-----
H-3b2	3.2×10^{-6}	-7.6	-----	0.04	-----
H-3b2 (1986, pump)	1.8×10^{-6}	-8.1	-----	0.03	-----
H-3b1	1.9×10^{-6}	-7.7	-----	0.25	-----
H-3b3	1.9×10^{-6}	-8.0	-----	0.10	-----
H-11b1 (1984, pump)	1.2×10^{-5}	-3.3	-----	0.01	1.3×10^{-9}
H-11b2	2.5×10^{-5}	-----	8.0×10^{-4}	0.35	2.0×10^{-6}
H-11b3	2.8×10^{-5}	-----	5.5×10^{-4}	0.35	1.3×10^{-6}
H-11b2 (1984, pump)	-----	-----	-----	-----	-----
H-11b1	2.7×10^{-5}	-----	6.1×10^{-4}	0.43	2.0×10^{-6}
H-11b3	2.6×10^{-5}	-----	4.5×10^{-4}	0.40	3.8×10^{-6}
H-11b3 (1984, pump)	2.8×10^{-5}	-4.4	-----	0.01	2.3×10^{-6}
H-11b1	2.7×10^{-5}	-----	6.3×10^{-4}	0.30	1.3×10^{-6}
H-11b2	2.6×10^{-5}	-----	7.2×10^{-4}	0.30	1.3×10^{-6}
H-11b3 (1985, pump)	3.0×10^{-5}	-4.6	2.9×10^{-3}	0.01	3.7×10^{-7}
H-11b1	2.7×10^{-5}	-----	2.9×10^{-3}	0.07	5.0×10^{-6}
H-11b2	2.8×10^{-5}	-----	2.6×10^{-3}	0.07	5.8×10^{-6}

---

[a] Slightly modified from data contained in Tables 6-1 and 6-3 of Beauheim (1987) and Table 6.1 of Saulnier (1987).

[b] All wells not labeled "well" were observation wells.

[c] All wells at the H-3 pad were interpreted as part of the pumped well; therefore, storativities are not available, but skin factors and point transmissivities are available for all wells.

TABLE 4.11 Summary of the analytical interpretation of results from the H-3 multipad interference test[a]

Well	Distance (m)[c]	Direction[c]	Time of first observation drawdown (hr)[d]	Delay in Max Drawdown (hrs)	Unmodified interpretation[b]		Modified interpretation		Water-level modification (m/day)
					Transmissivity[e]	Storativity	Transmissivity[e]	Storativity	
H-11b1	2423	S42E	79	51	1.4×10^{-5}	6.6×10^{-6}	7.3×10^{-6}	7.4×10^{-6}	8.6×10^{-3}
DOE-1	1606	S68E	57	48	9.9×10^{-6}	9.2×10^{-6}	5.9×10^{-6}	1.0×10^{-5}	5.5×10^{-3}
H-1	815	N19W	488	1423	8.9×10^{-7}	3.9×10^{-5}	4.9×10^{-7}	2.7×10^{-5}	2.64×10^{-2}
H-2b2	1270	N54W	433	1393	2.7×10^{-6}	4.5×10^{-5}	1.3×10^{-6}	3.0×10^{-5}	1.16×10^{-2}
WIPP-19	1875	N2E	1207	1855	3.1×10^{-6}	2.9×10^{-5}	--	--	--
WIPP-21	1437	N3E	437	678	1.2×10^{-6}	9.0×10^{-5}	--	--	--
WIPP-22	1739	N2E	990	727	1.7×10^{-6}	1.7×10^{-5}	--	--	--

[a] Slightly modified from data contained in Tables 3-1, 5-1, and 6-4 of Beauheim (1987a).

[b] Unmodified and modified transmissivities and storativities are apparent average values between H-3b2 and the indicated well, assuming radial flow to H-3b2.

[c] Distances and directions measured from H-3b2 to the indicated well.

[d] Times of the first drawdown and delay in the maximum drawdown are relative to time at which pump was turned on and off, respectively.

[e] Transmissivitiy in square meters per second.

The transmissivity distributions calculated (Haug et al., 1987) are shown in Figure 4.17. The distribution was developed through the use of the SWIFT II code, test data from the H-3 multipad interference test, and adjustments for fluid density effects in the eastern half of the model.

Haug et al., (1987) also investigated whether or not a porous flow numerical approach could adequately model the Culebra Dolomite fractured system on a regional scale. Transient hydraulic responses to shaft sinking and sealing at hydropad H-3, and the H-3 multipad interference test, were modeled using both dual porosity and porous media methods. These modeling efforts indicated that dual-porosity methods of flow system simulation are not needed at a regional scale.

The second multipad interference test was centered at hole WIPP-13 (Figure 4.12). The pumping phase at WIPP-13 took place between January 12, 1987 and February 17, 1987. Analytical estimation of hydraulic parameters resulting from the WIPP-13 test are discussed by Beauheim (1987c). These estimated hydraulic values for transmissivity and storativity are summarized in Table 4.12.

The numerical simulation of the Culebra hydrology, including the region stressed in the WIPP-13 tests, using the SWIFT II code is discussed in LaVenue et al., (1988). The emphasis of the numerical simulation study is on the Culebra hydrology prior to 1981 when construction of WIPP shafts imposed stress on the hydraulic system. Detailed interpretation of the WIPP-13 multipad interference test is still ongoing. However, transmissivities calculated for this modeling effort, based on steady-state calibration against estimated fresh-water levels, are shown in Figure 4.18.

The third multipad interference test was centered at hydropad H-11 during the summer of 1988. Evaluation of this interference test is still underway. Preliminary results indicate that the zone of high permeabilities shown on Figure 4.18 probably extends as far north as DOE-1.

4.3.3.3 Basis for the Culebra Dolomite Flow and Transport Model. Modeling of the Culebra Dolomite hydrologic system has undergone dramatic changes since the FEIS. These changes reflect modifications to the conceptual model of the Culebra system. Current understanding shows that the Culebra Dolomite is a more complex flow system than originally conceptualized.

From 1983 through 1988, new hydrologic data for the Culebra Dolomite were collected and old data were reinterpreted, leading to a revised conceptual model of flow within the Culebra Dolomite. Although fracture characteristics of the Culebra Dolomite were recognized early in the hydrologic characterization of the WIPP site (Mercer and Orr, 1979), early models treated the Culebra as a simple porous media. Beauheim (1986) demonstrated the double-porosity hydraulic behavior of the Culebra during testing at well DOE-2. Subsequent analyses of pumping tests performed at H-3 (Beauheim, 1987a), WIPP-13 (Beauheim, 1987b), H-11 (Saulnier, 1987), and other wells (Beauheim, 1987c) showed that double-porosity behavior can be considered dominant wherever the Culebra has transmissivities greater than 10^{-6} m^2/s. In 1986, the DOE began a model-development process that will continue through at least 1989. The code used is SWIFT

TABLE 4.12 Summary of the analytical interpretation of results from the WIPP-13 multipad interference test[a]

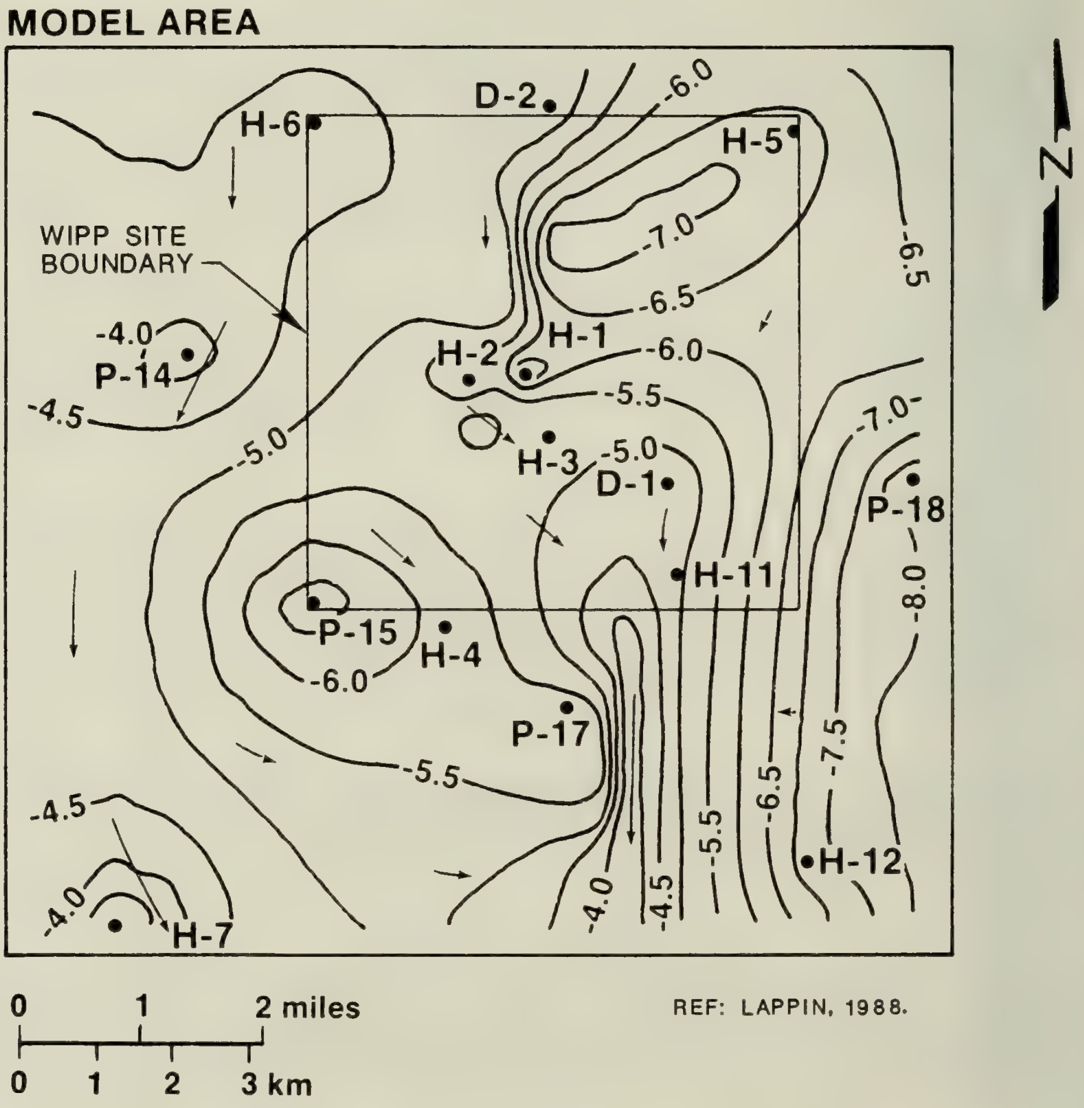
Well	Distance (m)[b]	Direction	Time of first[c] drawdown (hrs)	Delay in maximum drawdown (hrs)	Maximum drawdown (psi)	Transmissivity (m^2/s)[d]	Storativity	Water level modification (m/day)
WIPP-13	0	--	0	0		7.4×10^{-5}	--	--
DOE-2	1475	N45E	1	1	17.3	7.1×10^{-5}	5.1×10^{-6}	--
H-6a	2192	N20W	8	5	7.7	7.6×10^{-5}	8.2×10^{-6}	--
H-6b	2189	N20W	8	5	7.9	7.4×10^{-5}	7.9×10^{-6}	--
WIPP-30	5587	N12E	61	136	4.9	3.0×10^{-5}	5.6×10^{-6}	5.3×10^{-3}
WIPP-12	1283	S55E	74	186	11.9	8.5×10^{-6}	3.6×10^{-5}	4.5×10^{-3}
WIPP-18	1521	S45E	74	86	9.3	2.5×10^{-5}	4.0×10^{-5}	3.6×10^{-3}
WIPP-19	1823	S37E	102	186	7.2	2.6×10^{-5}	4.0×10^{-5}	7.6×10^{-3}
WIPP-21	2216	S29E	133	396	3.6	2.4×10^{-5}	4.3×10^{-5}	1.7×10^{-2}
WIPP-22	1933	S34E	102	286	5.7	2.0×10^{-5}	4.7×10^{-5}	8.2×10^{-3}
H-1	2676	S16E	600	2086(?)	1.1	2.2×10^{-5}	1.3×10^{-4}	1.4×10^{-2}
H-2b2	2597	S20E	445	986	1.4	1.7×10^{-5}	7.3×10^{-5}	6.0×10^{-3}
ERDA-9	2518	S24E	550	396	2.0	2.4×10^{-5}	5.4×10^{-5}	1.6×10^{-2}
Exhaust shaft	2414	S26E	400	336	3	3.0×10^{-5}	5.5×10^{-5}	2.9×10^{-2}
P-14	4228	S58W	71	56	0.8	2.8×10^{-4}	5.2×10^{-5}	--
WIPP-25	6264	S88W	76	26	0.3	7.0×10^{-4}	6.4×10^{-5}	--

[a] Slightly modified from data contained in Tables 3-1, 5-1, and 6-4 of Beauheim (1987c).

[b] Distance and direction measured from WIPP-13.

[c] The time of the first drawdown and the delay in the maximum drawdown are relative to the time at which the pump was turned on and off, repsectively.

[d] Apparent and effective transmissivity (T) and storativity (S) assume homogenous properties between WIPP-13 and given well, as well as radial flow into WIPP-13.



REF: LAPPIN, 1988.

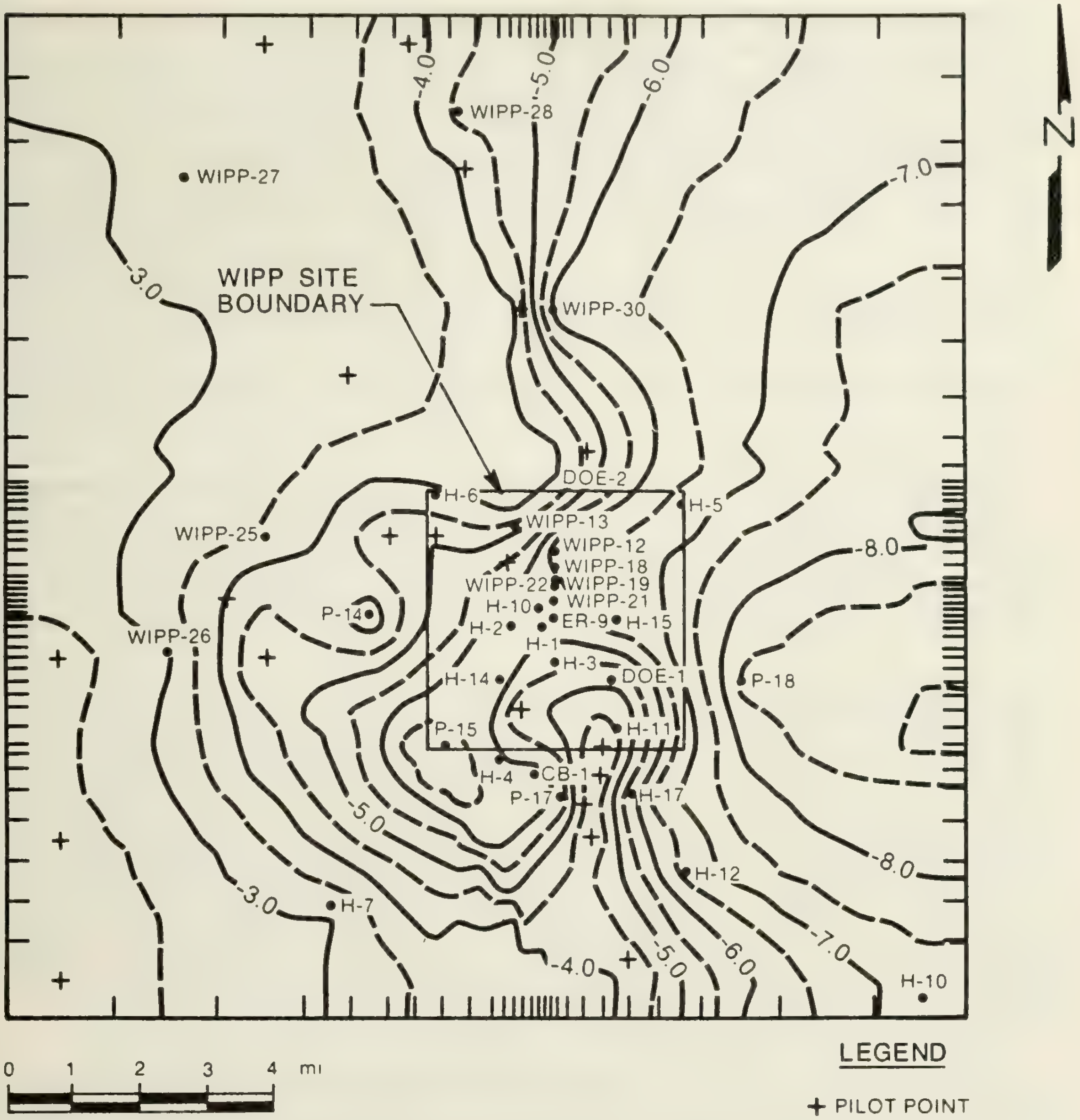
NOTES: 1) UNITS: LOG m^2/s.

2) ● = DATA POINTS.

3) BASED ON DATA AVAILABLE AS OF APRIL 1986.

4) CONTOUR INTERVAL: 0.5 UNITS.

FIGURE 4.17
FINAL CALCULATED TRANSMISSIVITIES AND FLOW DIRECTIONS FOR THE CULEBRA DOLOMITE MEMBER



LAVENUE et al., 1988.

FIGURE 4.18
CALCULATED TRANSMISSIVITIES FOR THE CULEBRA
DOLOMITE MEMBER AT AND NEAR THE WIPP SITE

II (Reeves et al., 1986a, 1986b), an enhanced version of SWIFT that can simulate double-porosity flow and transport.

Model development by LaVenue et al., (1988) incorporated new data on transmissivities and hydraulic heads, the results of the multipad interference tests. Calibration of the model of LaVenue et al., (1988) indicated a high-transmissivity feature south of H-11 and DOE-1. The feature was somewhat wider in the east-west direction, and the transmissivities calculated for this zone (Figure 4.18) are approximately four times lower than those reported in Haug et al., (1987) (Figure 4.17). Particle travel time from the center of the WIPP emplacement panels to the southern WIPP-site boundary, along the present hydraulic gradient, was computed to be approximately 13,000 years. The model of LaVenue et al., (1988) is being expanded to accommodate the calibration of both steady-state and transient flow within the Culebra.

Transient hydraulic stresses that are currently being included in this most recent model-calibration procedure consist of the WIPP shaft construction; the H-3, WIPP-13, and H-11 multipad pumping tests; and the H-4 tracer test. This model is termed the "adjoint-sensitivity approach" and allows minor modification of assumed transmissivities or storativities to improve the model fit to the observed hydraulic heads. The adjoint-sensitivity approach will also permit modeling of different conceptualizations of the flow system that fit the observed head distribution equally well, but may result in different flow paths or travel times from the waste-disposal panels to the site boundary.

The data-collection phase of the Culebra hydrologic characterization program is essentially complete. Some (re)interpretation of existing data remains (because of the absence of wells) to be completed, notably for wells H-4, H-6, H-7, H-9, and P-14. Data gaps in well distribution (because of the absence of wells) also exist (e.g., in the northeastern quarter of the WIPP site; west of H-12 in the assumed high-transmissivity feature; between H-7 and H-9; and east of H-8); no new wells are currently planned. Thus, modeling will be bound by the limitations of the current data base. The significance of these limitations will not be known until the calibration of the transient adjoint-sensitivity groundwater-flow model is completed. Currently, the unexpanded version of the model of LaVenue et al., (1988) model (version L) is being used to make the long-term-performance predictions presented in Subsection 5.4.

Within the context of the current hydrologic code used to simulate the Culebra flow and transport characteristics, various assumptions have been made. First, the Culebra has been assumed to be vertically homogeneous, with hydraulic conductivity, and hence flow, distributed equally throughout the thickness of the unit. In limited testing performed at five locations, Mercer and Orr (1979) and Beauheim (1987c) have shown hydraulic-conductivity variations ranging from a factor of 2 to a factor of 5 between different intervals within the Culebra (i.e., sections on the order of 1 or more meters thick). However, the area flow modeling of the Culebra relies on transmissivity data, not hydraulic-conductivity data, and flow and transport modeling should be reliable.

A second assumption used in the Culebra flow and transport modeling in this report (as opposed to Haug et al., 1987) is that the Culebra is locally completely confined, with no vertical flow either in or out, and that both brine-density distribution and head potential are at steady state. Although the impact should be minimal, to date the uncertainty of the modeling related to the transient setting has not been fully evaluated.

A third assumption of the current generation of Culebra hydrologic models is that the Culebra is locally a hydraulically isotropic medium (having uniform properties in all directions). Gonzalez (1983) and Saulnier (1987) reported evidence that the ratios of horizontal anisotropy (exhibition of properties that are different in one or more directions) ratios range from 1.6/1 to 2.7/1 within the Culebra. Implementing an anisotropy ratio of 2.7/1 within the model would only require changing the current effective transmissivities by a factor of 1.6, which is well within the existing calibration uncertainty.

4.3.3.4 Geochemical Environment Within the Rustler Formation. As detailed in the preceeding sections, the Rustler Formation is composed of three beds of anhydride, rock salt, and clays separated by two beds of finely crystalline gypsiferous dolomite (Lappin, 1988).

Because of the potential importance of the Culebra Dolomite as a migration pathway, numerous wells have been emplaced within the bed. Chemical analyses of samples from these wells indicate that there are four distinctive hydrochemical facies (distinguishable water quality types) within this unit (Siegel et al., 1988). The distribution of these facies is shown in Figure 4.19. The hydrochemical facies are distinguished in terms of their major constituents (Siegel et al., 1988).

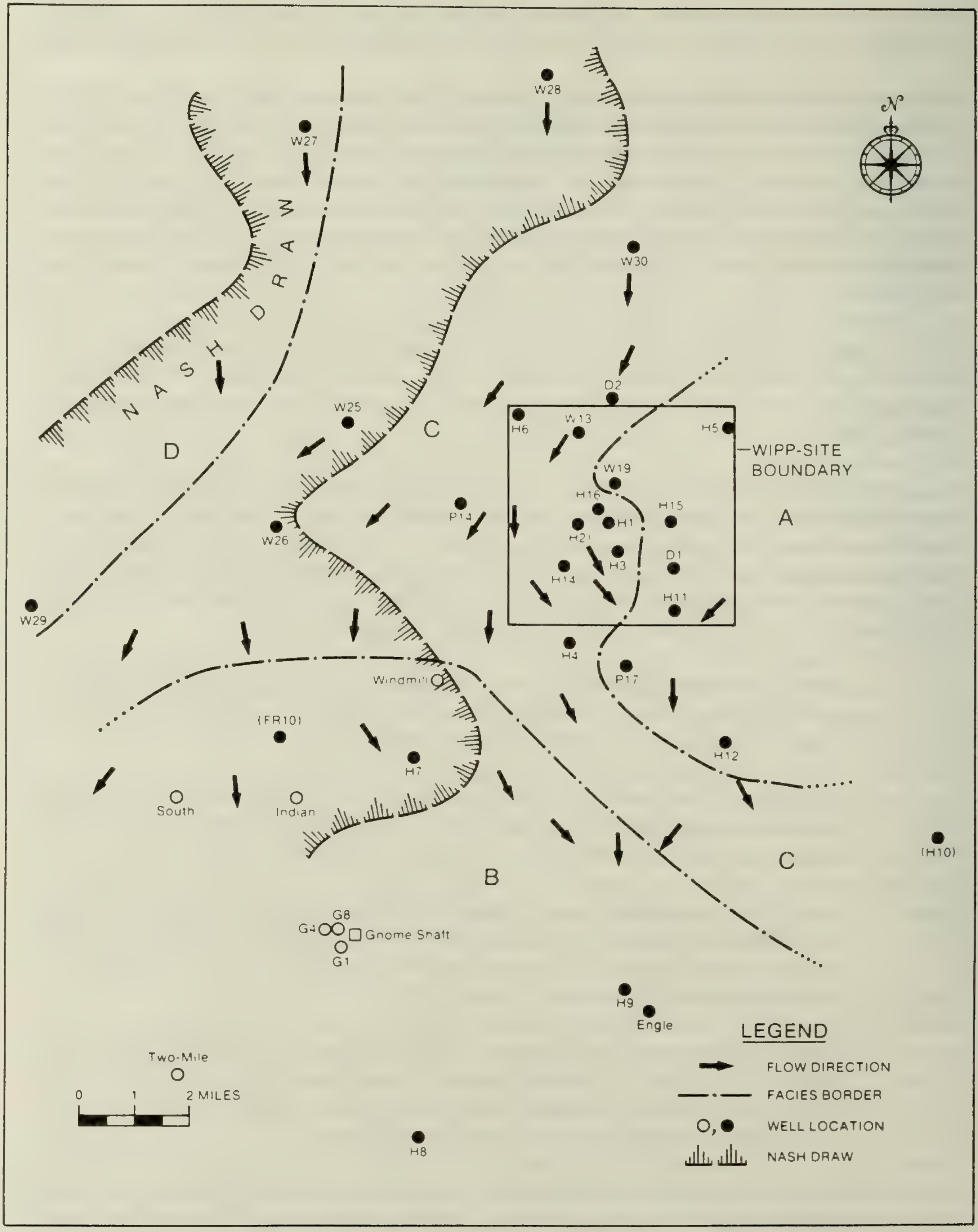
- Zone A contains a solute of 2 to 3 molal sodium chloride (NaCl) brines with a calcium/magnesium (Ca/Mg) ratio near unity. The Zone A brines are limited to the eastern portion of the WIPP site.

- Zone B is characterized by relatively fresh (<0.1 molal) water in which the major components are the calcium ion (Ca^{2+}) and sulfate (SO_4^{2-}). The Zone B fluids are restricted to the southern portion of the region.

- Zone C contains liquids of intermediate ionic strength, O.3 to 1.1 molal, and is distinguished by Ca/Mg ratios greater than 1.5/1. These fluids are found within a central zone that divides into two branches as one progresses to the southwest and southeast (Figure 4.19).

- Zone D fluids have anomalously high concentrations, 3 to 7 molal, and potassium/sodium (K/Na) ratios that are at least twice that of the other brines (0.2 vs .0.01 to 0.09). Zone D is limited to the northwestern portion of the region and across Nash Draw from the WIPP site.

Siegel et al., (1988) conducted a principal component analysis (PAL) to determine whether the fluids from all four hydrochemical facies could be variations of the same parent fluid. These results suggest that the Culebra fluids are variously buffered by the dissolution of rock salt, gypsum/anhydrite, and carbonates, and in some cases the magnesium ion (Mg^{2+}) and silica (SiO_2) are added to the groundwater in response to



REF: LAVENUE et al., 1988.

FIGURE 4.19
SUMMARY OF HYDROCHEMICAL FACIES AND
LOCAL FLOW DIRECTIONS IN THE CULEBRA DOLOMITE MEMBER

clay diagenesis. There is not, however, a direct correlation between the mineralogy of the Culebra and hydrochemical facies.

The details of the mineralogy of the Culebra Dolomite are described in Siegel et al., (1988). Eighty-five percent of the bulk rock is composed of relatively pure dolomite ($CaMg(CO_3)_2$). Accessory minerals include gypsum, ($CaSO_4 \cdot 2H_2O$), calcite ($CaCO_3$), and clays, which are distributed heterogeneously both horizontally and vertically. Fracture fillings include both clays and gypsum. Gypsum is also found as a filling in solution cavities and holes within the Culebra Formation. Detailed investigations of the clays by Sewards et al., (1988) indicate that an ordered, mixed-layer illite-smectite is the most abundant clay mineral and, indeed, the most abundant mineral after dolomite. Additional sheet silicate minerals include illite, chlorite, and amesite, a serpentine-like mineral. While there are major variations in the mineralogy of the Culebra Member of the Rustler Formation, there is no apparent correlation between host-rock mineralogy and hydrochemical facies.

4.3.4 Castile Formation

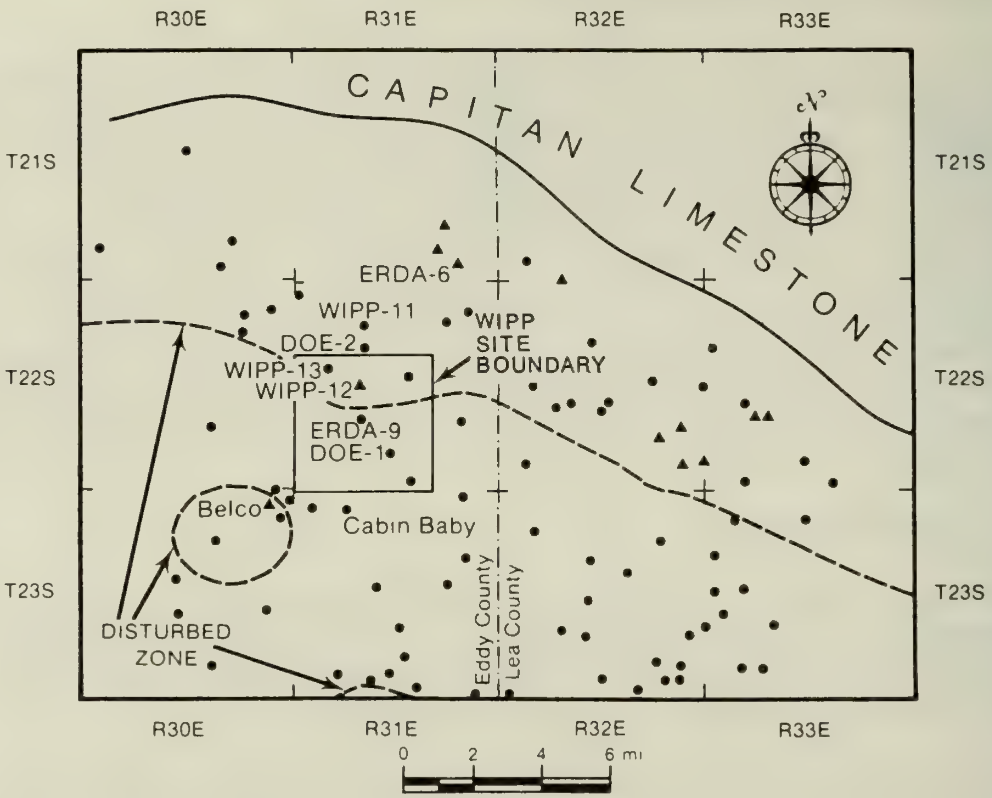
The Castile Formation lies below the Salado Formation and over the Bell Canyon Formation of the Delaware Mountain Group. At and near the WIPP, the Castile Formation consists lithologically of three anhydrite units separated by two halite units. Total thickness of the Castile is approximately 1312 ft.

Figure 4.5 shows the distribution of the anhydrites (Anhydrite I at the bottom and Anhydrite III at the top) and the intervening halite units (Lappin, 1988). This figure represents the current understanding of the Castile Formation at and near the WIPP.

4.3.4.1 Regional and Local Variability, Deformation, and Dissolution of the Castile Formation. Concern regarding the variability of the stratigraphic thickness of the Castile and its potential cause by regional or localized dissolution was expressed prior to the FEIS (Anderson, 1978) and more recently by Davies (1983). The thickness of the Castile varies regionally and locally within the WIPP site. The northern portion of the WIPP (Holes WIPP-12, DOE-2 and WIPP-11) lies within the disturbed zone described by Borns et al., (1983) (Figure 4.20), which potentially is characterized by deformation and variability in the thickness of the Castile and Salado Formations.

Much of the thickness variability shown in Figure 4.5 is within the halite units. However, Anhydrites II and III also vary in thickness. The relationship between the thickness of the halites and the anhydrites indicates unusually thick halites coupled with unusually thin anhydrites and vice versa. This thickness relationship is inconsistent with the concept of dissolution being the prime cause of the variation in the Castile Formation thickness.

A similar relationship is seen between the halites of the Salado and the predominant anhydrites of the Castile. This would indicate that the variable thicknesses of the halite and the anhydrite is due to internally compensating variations in the thickness of these



LEGEND

▲ BOREHOLE IN WHICH CASTILE FORMATION BRINE WAS ENCOUNTERED

● BOREHOLE THAT PENETRATED THE CASTILE FORMATION BUT DID NOT ENCOUNTER BRINE (ERDA-9 IS INCLUDED FOR REFERENCE ONLY)

REF: LAPPIN, 1988.

FIGURE 4.20
GENERALIZED DISTRIBUTION OF CASTILE FORMATION BRINE OCCURENCES AND APPROXIMATE EXTENT OF THE CASTILE "DISTURBED ZONE" IN THE NORTHERN DELAWARE BASIN

materials. The origin of this compensating relationship may be depositional (Lambert, 1983; and Borns and Shaffer, 1985) or a postdeposition gravity deformation (Borns et al., 1983).

Borns et al., (1983) and Borns (1983) cite considerable evidence for both syndepositional (concurrent with deposition) and postdepositional deformation of the Castile Formation. Concurrent depositional deformation is probably the result of gravity acting as the driving force along depositional slopes or in response to density contrasts. Postdepositional deformation results from high-stress-level anhydrous deformation (Munson, 1979) or pressure-solution deformation (Borns et al., 1983).

Recent studies indicate that the fluid content within the Salado Formation is as high as 2 percent, more than adequate for pressure-solution deformation (Borns, 1987). These studies indicate that much of the deformation of the Castile Formation may have been concurrent with deposition (i.e., Permian).

4.3.4.2 Occurrence and Characteristics of Pressurized Brines. The potential for the presence of pressurized brines within the Castile was recognized at the time of the FEIS. Seismic reflection data available at the time of the FEIS confirmed the presence of an area north of the site that exhibits nonuniform response to seismic waves. This zone (Figure 4.20) is the disturbed zone of Borns et al. (1983). Pressurized brines were encountered in hydrocarbon exploration drillholes and in ERDA-6 within the disturbed zone prior to the FEIS. In addition, brines were encountered to the southwest of the WIPP at the Belco well.

Investigation of pressurized brine in the Castile Formation has continued since the FEIS. These studies have included reopening and testing hole ERDA-6, deepening hole WIPP-12, geophysical investigations to identify the potential for the presence of Castile brines underlying the WIPP, and geochemical evaluations to determine the origin of the Castile brines. In these investigations, pressurized brines were encountered at a depth of about 3,000 ft in hole WIPP-12, and the disturbed zone and potential brine locations were delineated. A relatively recent origin was postulated for the brine.

Popielak et al., (1983) reported the results of the testing and sampling investigation in drillholes ERDA-6 and WIPP-12. The conclusions made from the ERDA-6 and WIPP-12 studies can be summarized as follows:

- The brines originated from ancient seawater, and there is no evidence of contribution from contemporary rainfall.
- The gas and brine characteristics at ERDA-6 and WIPP-12 are distinctly different from each other and from local groundwaters.
- These brines are at or near salt saturation and have little potential to dissolve evaporite deposits.
- The brine reservoirs at ERDA-6 and WIPP-12 were estimated to hold 630,000 and 17,000,000 barrels, respectively.

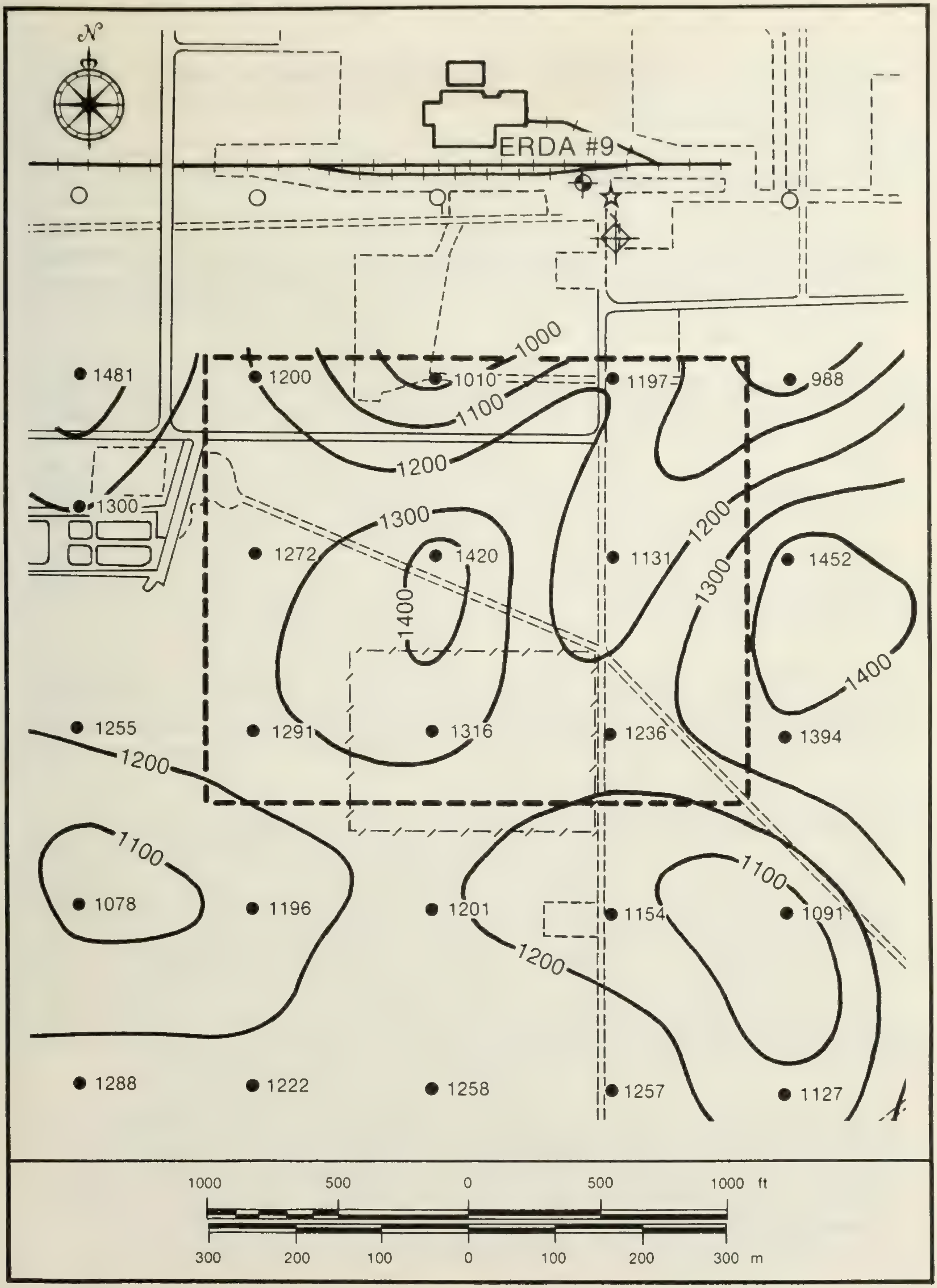
- The hydraulic heads measured in the brine reservoirs are great enough to reach the ground surface in an open borehole.

In a later study of brine geochemistry, Lambert and Carter (1984) indicate, on the basis of uranium disequilibrium, that the brines at ERDA-6 and WIPP-12 are between 360,000 and 800,000 years old. Because of these ages, Lambert and Carter conclude that the production of the brines must be episodic. This episodic process could have resulted from an intermittent hydraulic connection between the Capitan limestone and Castile anhydrites.

Geophysical studies reported by Borns et al. (1983) provided a delineation of the extent of the disturbed zone in the vicinity of WIPP (Figure 4.20). These studies were, however, unsuccessful in assessing the presence of Castile brines beneath the WIPP. A subsequent geophysical survey was conducted by Earth Technology (1987), using time-domain electromagnetic (TDEM) methods. This survey was conducted over WIPP-12, ERDA-6, DOE-1, and the waste disposal area. The results of this survey are presented in Figure 4.21. A continuous deep conducting zone underlies the region of the WIPP waste-emplacement panels (Figure 4.21). Conducting zones indicated at a depth of 3,935 ft. or less may be due to the presence of Castile brine, given the estimated +/-246 ft. in depth resolution and possible stratigraphic variability. Conductors indicated at greater depth are probably due to sandstone or shale in the underlying Bell Canyon Formation.

An earlier site proposed for the WIPP, approximately 6 miles north of the present site, was rejected partly on the basis of results obtained in hole ERDA-6 (Figure 4.20), which indicates both the presence of pressurized brine in Castile anhydrites and more, important strong deformation of the overlying Salado Formation (FEIS, Subsection 2.2.3). The deformation of the Salado would have required that a horizontal repository cross several stratigraphic contacts, including one or more anhydrite marker beds, and would have been in an area with increased potential for future deformation. The stratigraphic complexity in the Salado was especially important, because the proposed repository had two separate levels, one near the present repository horizon for RH TRU and CH TRU waste, and a deeper level near the Salado/Castile contact zone, for defense high-level waste (DHLW). Hole WIPP-12 (Figure 4.20) also encountered pressurized brine in the Castile, but the overlying Salado at this location is not significantly deformed (Figure 4.5). After brine was encountered in WIPP-12, the WIPP underground workings were reoriented to their present position. The major reason for this reorientation was to accommodate a request from the State of New Mexico. Calculations performed by both the WIPP Project and the State of New Mexico (Channell, 1982) indicated that the presence of pressurized Castile brine beneath the repository would not have unacceptable impact. The present orientation of the WIPP underground workings, with waste-emplacement panels south of hole ERDA-9, has allowed construction within a nearly flat-lying portion of the Salado.

The presence of Castile brine beneath the repository is of concern only in the event of human intrusion (Cases II A, B, C, D in Subsection 5.4). In this report, the brines underlying the repository are assumed to be present, as they are at WIPP-12. However, there is no direct pathway from the assumed brine reservoir to the repository



NOTE: THE SURVEY INCLUDES THE AREA OF THE WIPP UNDERGROUND REPOSITORY, AND THE HEAVILY DASHED RECTANGLE OUTLINES THE SURFACE PROJECTION OF THE WIPP UNDERGROUND REPOSITORY. CONTOURS ARE IN METERS.

REF: EARTH TECHNOLOGY, 1987.

FIGURE 4.21
CONTOUR MAP OF APPARENT DEPTH TO FIRST MAJOR DEEP CONDUCTOR

at present since, by design, no drillholes through the area enclosed by the WIPP workings have been allowed to penetrate down to the stratigraphic interval potentially containing Castile brines.

4.3.5 Bell Canyon Formation

The Bell Canyon Formation, which underlies the Castile Formation and is the uppermost formation in the Delaware Mountain Group, is of interest to WIPP site characterization because it is the first laterally continuous, water-bearing zone below the underground WIPP facilities. It has been considered as providing a potential local mechanism for the dissolution of the overlying evaporite sequences.

4.3.5.1 Dissolution Potential of the Bell Canyon Formation. The Bell Canyon Formation has been proposed as a point-source for the dissolution of the overlying evaporite sequences by Anderson (1978, 1981) and Davies (1983). The SPVD studies concluded that, even considering maximum potential dissolution rates at the top of the Bell Canyon Formation, no significant evaporite dissolution would be observed at the WIPP facility for at least 10,000 years. Additionally, Lambert (1983) concluded that the isotopic compositions of water in the Bell Canyon Formation show no evidence of a modern hydraulic connection with a salt unsaturated source of fluids like the Capitan Limestone. Therefore, the Bell Canyon Formation is not recharged with groundwater capable of dissolving overlying units over a long period of time.

4.3.5.2 Potential for Fluid Flow Between the Bell Canyon and the Rustler Formations. In the event of a drillhole interconnecting the Bell Canyon Formation and the Rustler Formation, the hydraulic pressure within the Bell Canyon could drive groundwater above the base of the Culebra Dolomite Member (Saulnier, 1987; Mercer et al., 1987; LaVenue et al. 1988; Uhland et al. 1987).

The freshwater head for the Bell Canyon at the center of the WIPP was calculated by Mercer et al., (1987) to be approximately 3412 ft. This would be 394 ft greater than the expected density-corrected pressure for the Culebra at the same location and indicates that, under these conditions, upward vertical flow could occur. However, Lappin (1988) argues that in the event of a breach interconnecting the Bell Canyon to the overlying units, local dissolution of the Salado would occur, so that the intruding fluids would become a saturated brine solution. Given this assumption, the hydraulic head of the Bell Canyon fluids would rise to an elevation of approximately 2739 ft in an open hole --that is, below the base of the Culebra Dolomite. This would result in an effective downward flow from the Culebra to the lower units.

Lappin (1988) agrees that the calculated direction of fluid flow depends on fluid densities and that fluid flow might move upward until the Bell Canyon and Culebra fluids were saturated with salt. This scenario also does not take into account the potential for gas pressure generation in the WIPP facility, which could provide driving pressure levels in both an upward and a downward direction.

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5.0 ENVIRONMENTAL CONSEQUENCES

This section discusses the potential environmental consequences of the Proposed Action, No Action, and the Alternative Action.

Subsection 5.1 provides an update of information discussed in the FEIS based on new information obtained since 1980 and discusses impacts that have occurred since 1982 as a result of WIPP construction activities. The information presented in Subsection 5.1 is not considered to be a substantial change from impacts foreseen in the FEIS.

Subsection 5.2 discusses impacts of the SEIS Proposed Action. Impacts at the WIPP during the Test and Disposal Phases remain the same as impacts described in the FEIS except as modified in Subsection 5.2. That subsection begins with an update of FEIS Section 9.8 which dealt with impacts of retrieval and processing of waste at the Idaho National Engineering Laboratory for shipment to the WIPP. Subsections 5.2.2, 5.2.3, and 5.2.4 evaluate the transportation, radiological, and hazardous chemical impacts, respectively, of the Proposed Action.

Subsection 5.3 evaluates impacts associated with the alternative of conducting bin-scale tests at a location other than the WIPP underground (Alternative Action). Also provided are the impacts of the decommissioning and long-term performance of the WIPP as a permanent waste repository are found in Subsection 5.4. The impacts of the No Action Alternative are found in Subsection 5.5.

5.1 ENVIRONMENTAL IMPACTS OF IMPLEMENTATION OF FEIS SELECTED ALTERNATIVE

This subsection updates the FEIS by describing impacts of construction as they have occurred and also discusses the findings of research since 1980.

5.1.1 Biology

Sections 9.2.1 and 9.3.1 of the FEIS describe the expected impacts on the biota from the construction and operation of the WIPP, respectively. The following discussion summarizes and updates the findings contained in the FEIS and the annual reports of the Environmental Monitoring Program (EMP) (Reith and Louderbough, 1986; Fischer, 1985, 1987, 1988).

- Vegetation. Impacts on vegetation currently consist of the continued use of cleared areas and the dispersion of salt and other mined-rock particles at the surface. Since the berms of the salt pile channel runoff to holding ponds, nearly all dispersion occurs through the resuspension, transport, and deposition of salt particles by wind. Observations at the Gnome-site salt pile indicate that these impacts are not considered to be major (i.e., the vegetation in the area shows no identifiable salt-related stress except for a single mesquite tree growing on one of the salt piles).

Vegetation and soil chemistry at the WIPP site and adjacent areas have been monitored since 1984 in permanent ecological monitoring plots to assess the impacts of the salt. Parameters that are monitored include foliar cover for all species, density of annual species, species richness, vegetative community structure, and soil properties (SEIS Section 2.9.2). The ecological impacts of excavated salt stored on the surface have been shown by the results of the monitoring programs to be considerably less than expected in the FEIS, as discussed below.

Ecological monitoring results showed a decrease in foliar cover for shrubs from spring to fall in the 1985 to 1987 study period. Both perennial and annual forbs and perennial grasses increased in foliar cover between 1985 and 1986 but decreased in 1987. These changes are believed to be the result of natural processes (e.g., available moisture, forage utilization) rather than the effects of the salt pile.

Annual species density showed a large fluctuation between 1985 and 1987, when high spring precipitation produced a high emergence of annual plants, and in 1986, when low spring rainfall may have delayed or hindered germination. In 1985 and 1987, the total densities of these plants decreased from spring to fall except in 1986 when there was a slight seasonal gain. This parameter is influenced by a number of factors, including soil types, seed viability, temperatures, size of seed crop from the previous year, and amount of grazing by cattle and herbivorous wildlife.

The concentrations of soluble ions in surficial soil samples have been most affected by salt dispersion. These concentrations, particularly of sodium and chloride, have been substantially higher at monitoring plots adjacent to salt piles than at control plots, with the highest concentrations occurring in the spring. This pattern suggests that salt is picked up and deposited downwind by the strong spring winds; the salts are then leached downward through the sandy soil during summer rainstorms. The salt levels in the soil, however, do not appear to inhibit plant species diversity or abundance.

- Wildlife. Data concerning the populations of breeding birds and small nocturnal mammals are being collected in two transects at the WIPP site and two transects at control locations. These data will be used to assess the impacts of habitat modifications associated with both construction and operational activities. Eleven species of dominant breeding birds were recorded in both the WIPP site and control transects throughout the years between 1984 and 1987; the most abundant of these species were the black-throated sparrow and pyrrhuloxia. Ten less abundant species were recorded along control transects, but only six of these species were found in the WIPP site transects. Eleven additional species were found only in WIPP site transects; the northern oriole (*Icterus galbula*) and the greater roadrunner (*Geococcyx californianus*) were the most numerous of these. A total of 28 species were recorded in the WIPP site transects while 21 species were recorded in control transects.

A total of 21 species of raptors have been recorded to date by surveys for the WIPP Biology Program (initiated in 1975) and its successor, the EMP. Two species, the Harris hawk and Swainson's hawk (*Buteo swainsoni*), were found to breed near the WIPP site in unusually large numbers. This was an important finding because both species are uncommon in the United States and are of uncertain status throughout most of their natural range. Since human influence adversely affects the nesting success of these birds, modifications of field work schedules were modified to avoid disturbance of active nests.

Mammal population densities were estimated by trap, mark, and recapture techniques performed over the 1985-1987 period. The species considered were Ord's kangaroo rat (*Dipodomys ordii*), plains pocket mouse (*Perognathus flavescans*), northern grasshopper mouse (*Onychomys leucogaster*), southern plains woodrat (*Neotoma micropus*), white-footed and deer mice (*Peromyscus leucopus* and *maniculatus*), and hispid cotton rat (*Sigmodon hispidus*). Of these, the Ord's kangaroo rat and the plains pocket mouse were the most common, while the hispid cotton rat and the white-footed and deer mice were the least abundant. The kangaroo rat was present in all transects during all years. The pocket mouse, though present in all years and in all transects, was characterized by an extremely low population in 1986.

On-going studies seem to indicate that human activity has a disturbing influence on some bird species and displaces some individuals or species. Mammal populations show large natural fluctuations, but do not appear to have been influenced by WIPP construction activities.

In some cases, however, the activity at the WIPP site creates an artificial environment that attracts species which are not otherwise common to the area.

5.1.2 Socioeconomics

Socioeconomic evaluations for the WIPP were presented in the 1980 FEIS in Sections 6.6, 6.12, and 9.4.

Socioeconomic impacts on southeastern New Mexico were studied for FY 1982 (Adcock et al., 1983), FY 1987 (Lansford et al., 1988a), and FY 1988 (Adcock et al., 1989). A comparison of current economic conditions and impacts with those projected in the FEIS shows some dramatic differences. The differences are mainly a result of WIPP design changes, increased construction efficiency, and cyclic economic conditions (reductions in potash, oil, and gas production). The WIPP-related changes had a stabilizing effect on the local economy, particularly in Eddy County.

The primary area of socioeconomic impact defined in the 1980 FEIS was, and continues to be, Eddy and Lea Counties, or southeastern New Mexico. The local WIPP funding, or direct impact on this area, was $72.5 and $95.3 million in Federal FY 1987 and FY 1988, respectively. This includes monies for local DOE offices, Sandia National Laboratory, Westinghouse Inc., and various on-site support contractors. Also included are grants, community assistance, and out-of-region expenditures made through or by the local WIPP project office. Local spending was mainly for wages and salaries, materials and services, capital equipment, and construction. Subsequent spending of these salaries and wages and other indirect effects pushed the total impact of the WIPP project to an estimated $159.4 million in FY 1987 and $208.9 million in FY 1988 (Lansford et al., 1988b; Adcock et al., 1989). The data for FY 1988 are given in Table 5.1.

WIPP's direct activity created an average of 530 and 661 jobs in FY 1987 and FY 1988, respectively. Total employment impacts were 1,434 and 1,814 new jobs in FY 1987 and FY 1988, respectively.

The WIPP project injected more than $18 million in personal income directly into the local economy in FY 1987 and more than $24 million in FY 1988. WIPP-related purchases and respending generated additional personal income through wages and salaries of individuals not directly connected to the WIPP. The estimated total personal income additions from WIPP activity in southeastern New Mexico were $38 million in FY 1987 and over $50 million in FY 1988.

During 1987, the DOE Albuquerque Operations Office (DOE/AL) announced a commitment to assemble the TRUPACT-II containers in southeastern New Mexico. The contract for this assembly facility was awarded to a Carlsbad firm. Construction of the facility was completed in February 1987, with a total cost of about $800,000. The assembly of the TRUPACT-II containers created 17 new jobs in Carlsbad during 1987, with an estimated 40 additional jobs in 1988.

In November 1988, DOE/AL signed a contract with a Farmington, New Mexico, firm to transport waste in TRUPACT-II containers to WIPP from the generator sites. The contract is estimated to be worth up to $5.8 million over a period of up to five years.

With the proposed initiation of the Test Phase in 1989, continuing for approximately five years, the annual total economic impact would range from about $150 million to $185 million (constant 1990 dollars). The direct employment for the regional WIPP activity would range between 650 and 660 jobs during this time period. The annual total employment range would be 1,650 to 1,800 jobs, depending on the regional expenditure patterns during this period.

By 1995 the WIPP would have reached steady operation with a funding (in 1990 constant dollars) of $67 million annually. At this level of funding, the annual total economic impact on southeastern New Mexico is projected to be $160.5 million. The steady-state period would continue through FY 2013. Direct annual employment would average 680 jobs. Projected indirect (including induced effects) employment effects would be about 930 jobs. Thus, the total employment effect of the WIPP during this period would be about 1,610 jobs, either created or indirectly supported. During this period, annual total personal income would be increased by $43 million from all impacted sources. Over the

TABLE 5.1 WIPP's influence on the regional economies of Eddy and Lea Counties, FY 1988

	WIPP Activities	Regional Economies	WIPP % of Regional Economies
	(Dollars in Millions)		
Economic Activity			
Direct Expenditures	$ 95.3		
Indirect and Induced[a]	113.6		
Total	$208.9	$4,000.0	5.2
Income			
Salaries and Wages[b]	$ 24.3		
Indirect and Induced[a]	26.2		
Total	$50.5	$1,400.0[c]	3.6
	(Number of Employees)		
Employment			
5 5-5	Table 5.1	The number 611 under Employment, Direct, should read 661.	
Total	1,814	39,500[d]	4.6

[a] Based on an econometric model maintained at Los Alamos National Laboratory.

[b] Less the fringe benefits that are not counted as personal income.

[c] Extrapolated 1984-86 personal-income data from Bureau of Economic Analysis, U.S. Department of Commerce.

[d] Table A, New Mexico Department of Labor, 1989.

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Income			
Salaries and Wages[b]	$ 24.3		
Indirect and Induced[a]	26.2		
Total	$50.5	$1,400.0[c]	3.6
	(Number of Employees)		
Employment			
Direct	611		
Indirect and Induced[a]	1153		
Total	1,814	39,500[d]	4.6

[a] Based on an econometric model maintained at Los Alamos National Laboratory.

[b] Less the fringe benefits that are not counted as personal income.

[c] Extrapolated 1984-86 personal-income data from Bureau of Economic Analysis, U.S. Department of Commerce.

[d] Table A, New Mexico Department of Labor, 1989.

20-year Disposal Phase, the WIPP would add over $1 billion (1990 constant dollars) to regional total personal income.

During the same period, local and state tax and fee revenues from all sources related to WIPP would be increased by $5.4 million annually or over $100 million for the operating period.

After FY 2013, decommissioning activities are planned to begin and would continue for up to five years. During this period the WIPP funding and employment would decrease.

Considering the total period from FY 1990 through FY 2018, funding for WIPP, in terms of constant 1990 dollars, would be over $2.1 billion. The economic activity multipliers used in the FY 1987 and FY 1988 studies by Lansford and Adcock (Lansford et al., 1988b; Adcock et al., 1989) were 2.20 and 2.19, respectively. The steady state multiplier determined for the report was 2.36–slightly higher due to higher proportion labor costs and increased proportional spending in the local area. The combination of these multipliers on the WIPP funding levels, shows a total impact on regional economic activity of over $4.3 billion from FY 1990 through decommissioning.

5.1.3 Land Use

The detailed evaluations contained in FEIS Section 9.4.5 remain valid and have not been reevaluated for this SEIS. The upgrading of site security facilities and the release of Control Zone IV for unconditional use have modified land use restrictions and have resulted in changes in the impacts projected in the FEIS. The upgrading of site security facilities would result in the denial of 1,200 acres of grazing land that would have supported 18 head of cattle per year. Unconditional release of Control Zone IV resulted in a much smaller impact on hydrocarbon and potash resources from that projected in the FEIS. Between 57 and 71 percent of the distillate, natural gas, crude oil, langbeinite, and sylvite resources projected to be lost will now be available for future extraction. Approximately 50 million tons of total potash resources (langbeinite and sylvite) are now available for extraction.

5.1.4 Air Quality

The air quality evaluations presented in Section 9.3.1 of the FEIS are still considered to be valid. The air quality monitoring program initiated in 1986 has indicated that the air quality in the area of the WIPP meets State and Federal standards except during periods when excessive dust is generated and during a 21-day period when sulfur dioxide levels exceeded standards for a 24-hour average. The dust has been attributed to location of the air sampler near a heavily used dirt road. The WIPP has not been determined to be responsible for the elevated sulfur dioxide levels. In 1988, hydrogen sulfide exceeded the standards as the result of paving operations. Also, in December 1988, ozone levels exceeded standards, but the cause has not been identified. In general, activities at the WIPP have had few short-term and no long-term impacts on air quality.

5.1.5 Cultural Resources

Two cultural resource evaluations have been performed since 1980 (SEIS Section 4.1), and these evaluations have provided additional insight into the use of the WIPP site area by aboriginal inhabitants. A site that would have been destroyed during the construction of the railroad spur was excavated and evaluated. No additional destruction of cultural resource sites is expected to occur from activities in support of the WIPP.

5.2 ENVIRONMENTAL IMPACTS OF SEIS PROPOSED ACTION

Impacts discussed in the FEIS for the current Proposed Action (Alternative 2 in the FEIS) are updated and/or modified by the information contained in this subsection and in SEIS Subsections 5.3 and 5.4. The primary areas of modification of impacts are transportation, hazardous chemicals, and radiological effects.

5.2.1 Waste Retrieval and Processing at the Idaho National Engineering Laboratory

About 61 percent of the pad-stored defense TRU waste in the United States is located at the Radioactive Waste Management Complex (RWMC) of the Idaho National Engineering Laboratory. Subsection 9.8 of the WIPP FEIS analyzed impacts associated with retrieving, processing, and handling TRU wastes at the RWMC. The following subsection updates the FEIS discussion by analyzing the environmental impacts of current TRU operations in Idaho and conceptually describing options under consideration for future processing facilities that would remove TRU waste from interim storage and prepare it for shipment to the WIPP.

5.2.1.1 Waste Characteristics and Current Management Methods. Since 1970, contact-handled TRU waste received at the RWMC has been stored at the 56-acre Transuranic Storage Area (TSA), a controlled area surrounded by a security fence. The waste is stored on three asphalt pads known as TSA-1, TSA-2, and TSA-R and in two covered enclosures. There is currently approximately 2.3 million cubic feet of TRU waste stored at the TSA.[a]

The solid TRU waste is received from the Rocky Flats Plant and other DOE facilities in government-owned ATMX railcars or on commercial truck trailers in Type B shipping containers. The ATMX shipments are made under the authority of a special permit issued by the Department of Transportation (DOT Exemption 5948). The waste is contained in 4 x 4 x 7 ft metal boxes with welded lids, 55-gallon steel drums with polyethylene liners, and 4 x 5 x 6 ft steel bins. (Some of the waste placed earlier on

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[a] Prior to 1982, TRU waste was defined as having a concentration of alpha-emitting radionuclides greater than 10 nCi/g TRU. In 1982, the definition was changed to include only those wastes with TRU concentrations greater than 100 nCi/g. As a result, about 1/2 of the 2.3 million ft^3 of waste stored at the RWMC is expected to be reclassified as low-level waste, and is not proposed to be shipped to WIPP.

the TSA was stored in containers of nonstandard sizes.) The containers are intended to be retrievable, and contamination-free for at least 20 years.

In the past, the drums and boxes were stacked on the TSA pads with boxes around the perimeter and drums in the center. The drums were stacked vertically in layers, with a sheet of 1/2-inch plywood separating each layer. When the stack reached a height of approximately 16 feet, a cover consisting of 5/8-inch plywood, nylon-reinforced polyvinyl sheeting, and 3 feet of soil was emplaced.

Currently, only precertified waste (i.e., in compliance with the WIPP WAC) is received from the generators and this waste is stored in a covered enclosure pending shipment to WIPP.

Other TRU waste operations that currently take place at the RWMC include the retrieval of drummed waste that has been stored in a covered enclosure located on the TSA-2 pad and certification of that waste to insure compliance with the WIPP WAC and appropriate transportation requirements.

This certification takes place in the Stored Waste Examination Pilot Plant (SWEPP) that provides non-destructive examination and assay capabilities to examine retrieved stored TRU waste. Only wastes meeting the WIPP WAC and transportation requirements could be shipped to WIPP. The facility contains a Real-Time X-Ray Radiography (RTR) system to examine the contents of both boxes and drums, an assay system to determine fissile and transuranic content, and a container integrity system to assure the waste drum meets Department of Transportation (DOT) metal thickness for Type A containers. In addition, the facility provides capabilities to puncture a drum lid using a sparkless tool and install a carbon composite filter to vent any radiolytic produced gas and provide for pressure equilibrium.

All drums are vented and examined at this facility after they are retrieved. Waste boxes are also examined using the RTR and the box assay system. Those waste packages that meet the WIPP WAC and transportation requirements are so labeled and stored awaiting shipment to WIPP. Those waste packages that do not meet the WIPP WAC would have to be further processed and repackaged before they could be shipped to WIPP.

More complete descriptions of the Idaho National Engineering Laboratory, the RWMC, the TRU waste storage and examination facility, and the TRU waste stored on the TSA pads can be found in the Safety Analysis for the Radioactive Waste Management Complex at the Idaho National Engineering Laboratory (DOE, 1986).

5.2.1.2 Environmental Effects of Current Operations. Current and hypothetical radiological effects associated with receiving, examining, venting, and storing TRU waste are presented below. These impacts are discussed for both workers and the general population as a result of normal operations and releases due to potential accidents and violent natural phenomenon.

Routine Operations. Measurable exposure to the public or adverse effects on the surrounding environment would not be expected from the extremely small airborne releases experienced during routine operations. No liquid effluents are expected during routine operations. Releases from normal operations are discussed in annual DOE environmental monitoring reports for the Idaho National Engineering Laboratory (DOE, 1987a). In keeping with the ALARA (As Low As Reasonably Achievable) philosophy, the radiological exposures to workers during normal operations are limited by monitoring accumulated personnel dose equivalents and by job preplanning. The maximum radiation exposure on external waste container surfaces are restricted to less than 200 mR/hr. Annual dose equivalents to RWMC personnel including operators, health physics technicians, and supervisors for all RWMC activities, including TRU waste operations, vary from a maximum of 306 mrem to less than 20 mrem. This is well below the established DOE occupational exposure limit of 5 rem per year (DOE, 1988a).

Accident Conditions. Safety documentation prepared for the current operations of the RWMC complex, which includes all TRU operations, evaluates the dose commitments and risks associated with potential operational accidents (e.g., fires, explosions, dropped containers) as well as those associated with hypothetical natural disasters (e.g., earthquake, volcanoes, lightning strike) (DOE, 1986). The projected consequences and risks of the dominant accident scenarios are summarized for the SEIS in Tables 5.2 and 5.3 for the general public and workers, respectively.

The highest exposure to a maximum individual member of the public is shown in Table 5.2 to be 2×10^{-2} rem committed whole-body dose equivalent. This exposure is associated with the occurrence of a tornado with 280 mile per hour winds, which has an extremely low probability of occurrence at the Idaho National Engineering Laboratory. The highest population exposure is also associated with the tornado and results in a collective dose equivalent of 1 person-rem. The excess risk to the total exposed population would be 2.8×10^{-4} excess cancer fatalities based on a multiplier of 2.8×10^{-4} latent cancer fatalities/person-rem.

Table 5.3 indicates that the highest exposure to the maximally-exposed worker is 0.7 rem, resulting from the fire in the air support weather shield. The risks of excess cancer to both the workers and an average member of the public are presented in Table 5.4.

5.2.1.3 Methods for Retrieving, Processing, and Shipping Waste. Several operations would be involved in removing the waste and shipping it to WIPP: 1) retrieval from earthen covered cells, 2) potential processing and packaging of the waste to meet current WIPP WAC and transportation criteria, and 3) shipping the waste. The WIPP FEIS evaluated several options for each operation.

Three methods of retrieving waste containers were considered: 1) manual handling by the operators; 2) handling by means of operator-controlled equipment; and 3) handling by means of remotely controlled equipment. A combination of the first two methods is under current consideration.

5.2 Summary of effects from accidental or uncontrolled releases during RWMC/SWEPP operations with stored TRU waste[a]

			Maximum Individual			Population		
			Committed Dose equivalent (rem) [b]			Collective Dose Equivalent (person-rem)[b]		
Event	Release fraction	Event frequency yr^{-1}	Body	Bone	Lung	Body	Bone	Lung
Tornado	5×10^{-4}	1×10^{-7}	2×10^{-2} [d]	4×10^{0} [d]	5×10^{-1} [d]	1×10^{0}	2×10^{3}	4×10^{3}
Earthquake[c]	8×10^{-8}	2×10^{-4}	2×10^{-7}	3×10^{-4}	4×10^{-4}	3×10^{-4}	4×10^{-1}	8×10^{-1}
Fire in ASWS/C&S	8×10^{-7}	1×10^{-3}	1×10^{-6}	3×10^{-3}	4×10^{-3}	3×10^{-3}	4×10^{0}	7×10^{0}
Breached Container	8×10^{-8}	6×10^{-4}	2×10^{-8}	3×10^{-5}	4×10^{-5}	3×10^{-5}	4×10^{-2}	8×10^{-2}
Explosion	5×10^{-7}	1×10^{-4}	2×10^{-3} [d]	3×10^{-2} [d]	2×10^{-2} [d]	2×10^{-4}	2×10^{-1}	4×10^{-1}

[a] Letter updating tables from WM-PD-86-011-Rev 2 (DOE, 1989).

[b] Exposure calculated using ICRP-2 dosimetry and methodology (DOE, 1986).

[c] Release due to damaged containers.

[d] The maximum annual dose equivalent and not the committed dose equivalent is stated.

TABLE 5.3 Summary of radiological consequences to the maximally-exposed worker from abnormal events during RWMC/SWEPP operations with stored TRU waste[a]

		Dose equivalent to maximally-exposed worker (rem)[b]					
	Event frequency	Inside facility			Outside facility		
Event	(yr^{-1})	Body	Bone	Lung	Body	Bone	Lung
Earthquake[c]	2×10^{-4}	1×10^{-1}	4×10^{0}	6×10^{0}	8×10^{-5}	1×10^{-1}	2×10^{-1}
Fire in ASWS/C&S	1×10^{-3}	7×10^{-1}	2×10^{1}	6×10^{1}	4×10^{-4}	8×10^{-1}	1×10^{0}
Breached Container	6×10^{-4}	1×10^{-2}	4×10^{1}	6×10^{1}	8×10^{-6}	1×10^{-2}	2×10^{-2}
Explosion	1×10^{-4}	2×10^{-3}	7×10^{-2}	4×10^{-3}	1×10^{-3}	4×10^{-2}	1×10^{-3}
Lightning Strike	4×10^{-6}	1×10^{-3}	2×10^{0}	4×10^{0}	1×10^{-6}	1×10^{-3}	2×10^{-3}

[a] Letter updating tables from WM-PD-86-011-Rev 2 (DOE, 1989).

[b] Exposure calculated using ICRP-2 dosimetry and methodology (DOE, 1986).

[c] Release due to damaged container.

TABLE 5.4 Excess cancer risks due to accidents associated with RWMC/SWEPP operations with TRU stored waste

	Excess Cancer Risk[a,b,c]		
Event	Maximum individual	Average member of population[d]	Maximally-exposed worker[e]
Tornado	$6x10^{-6}$	$2x10^{-9}$	nc[f]
Earthquake	$6x10^{-11}$	$7x10^{-13}$	$3x10^{-5}$
Fire in ASWS/CS	$3x10^{-10}$	$7x10^{-12}$	$2x10^{-4}$
Breached Container	$6x10^{-12}$	$7x10^{-14}$	$3x10^{-6}$
Explosion	$6x10^{-7}$	$4x10^{-13}$	$6x10^{-7}$

[a] Health risks are expressed as the probability of an individual contracting a fatal cancer during their lifetime as a result of RWMC/SWEPP related activities.

[b] Risk of contracting fatal cancer: $2.8x10^{-4}$ fatalities/person-rem (BEIR, 1980).

[c] Health effects risk estimates for genetic effects would be somewhat lower than the numbers presented in the table for cancer fatalities; by a factor of 0.918.

[d] Risk to an average member of the population is the product of the collective population exposure (Table 5.2) by $2.8x10^{-4}$ fatalities/person-rem divided by an estimated population of 129,000.

[e] Risk based on exposure within the facility (Table 5.3).

[f] Not calculated.

Four confinement methods for waste retrieval were considered: 1) open-air retrieval (no confinement); 2) the use of an inflatable fabric shield to protect against the weather; 3) the use of a movable, solid-frame structure operating at ambient pressure; and 4) the use of a movable or non-movable, solid-frame structure operating at subatmospheric pressure. The last method is the one currently being considered because it is the only one that provides positive control against the possible release of contamination.

Four potential processing options were also considered in the FEIS: 1) shipping as is, 2) overpacking, 3) repackaging only, and 4) treatment and packaging. A slagging pyrolysis incineration (SPI) process was proposed for waste treatment and was analyzed in detail in the FEIS. Incineration was the selected processing technology because it was anticipated that free liquid and combustible limitations in the WIPP WAC would make some of the stored waste unacceptable. Waste feed to the SPI was to be blended with glassforming compounds (soil) so the non-combustible ash would be melted at the incineration temperature and form a glass-like slag with low leachability. The molten slag was to be packaged in steel drums. Since 1980, this process was evaluated on an experimental basis and was proven inadequate for development for reliable treatment of stored TRU waste (Tait, 1983). No further DOE development of the process has occurred.

The following subsections discuss conceptual operations and facilities under current consideration for the retrieval, processing/packaging and shipping of TRU waste to the WIPP. At such time that proposed action(s) and/or alternatives are formulated, the appropriate NEPA documentation will be prepared for these new facilities and operations.

Retrieval Building and Operations. The retrieval building currently under conceptual design would be either a mobile or large fixed single-walled structure. Subatmospheric pressure would be maintained inside to prevent the escape of contaminants during retrieval operations. The ventilation system would include roughing filters and a bank of high-efficiency particulate air (HEPA) filters, for an estimated overall decontamination factor of 1000.

Prior to erection of the building over the retrieval area, most of the soil cover would be removed. After the building is in place, the remainder of the soil, the polyvinyl sheeting, and the plywood cover would be removed to expose the waste containers and permit retrieval.

Waste containers would be inventoried and examined to confirm their integrity. Any breached containers would be placed in a waste transfer container and loaded into a transfer vehicle. Forklifts would remove the intact containers from the stacks and place them into the transfer vehicle. The waste would be transferred from the retrieval building to the processing plant over DOE controlled roadways within the RWMC.

Processing for Repository Acceptance. Facilities are also under conceptual design to provide for the storage, treatment, and repackaging of the retrieved waste to make it acceptable for transportation and disposal at the WIPP. Noncertifiable drums and boxes would be segregated based on nondestructive examination into waste packages containing large metallic components, packages containing liquids or respirable/

dispersible fines, and oversize packages that do not meet transportation requirements. Treatment processes under consideration include size reduction using mechanical and plasma arc cutting to size reduce metallic components, immobilization to stabilize free liquids or respirable/dispersible fines, and shredding/compaction to shred and repackage boxed waste.

These facilities would be designed to ensure three levels of containment for all waste processing and repackaging areas. The ventilation system would be designed to maintain progressively lower pressures between the outside atmosphere and the waste processing areas. All air removed by the ventilation systems would pass through appropriate HEPA filtration systems for an estimated overall decontamination factor of 1000.

NEPA documentation will be prepared for these facilities under conceptual design to analyze the site specific impacts of the proposed retrieval, treatment and repackaging, and shipping activities at Idaho. These operations are scheduled to begin in 1992, and will be evaluated to determine the environmental effects including radiological risk to the public, hazards to workers, both radiological and nonradiological, and effects to the surrounding environment.

In addition to the facility discussed above, another processing system for TRU waste is being developed at the Idaho National Engineering Laboratory. A part of that system, known as the Process Experimental Pilot Plant (PREPP), involves low-speed shredding of the waste and containers, incineration in a rotary kiln incinerator, separation of the incinerated waste, and waste immobilization by cementing. This system is being developed in order to investigate possible treatment techniques for TRU waste that cannot presently be certified for shipment to WIPP. Some demonstration work involving non-hazardous, non-radioactive material has been performed at the PREPP facility. The DOE is currently preparing an Environmental Assessment to analyze the potential environmental impacts associated with processing TRU waste through PREPP.

5.2.2 **Transportation**

This section examines the potential environmental effects associated with the transportation of TRU waste from the generator and storage facilities to the WIPP. The FEIS assessed the impacts of transporting TRU waste to the WIPP from the Idaho National Engineering Laboratory in Idaho and the Rocky Flats Plant in Colorado. This SEIS estimates the cumulative risks associated with potential TRU waste shipments from 10 generator and storage facilities, as discussed in Subsection 3.1.1.3.

Differences in level of characterization of the radionuclide and hazardous chemical source terms required the use of different risk assessment methodologies for evaluating the radiological and hazardous chemical components of the TRU waste. The radiation exposure rate at the surface of the TRUPACT-II container was used to estimate the radiation dose equivalent to the population along the transportation routes to the WIPP. Since the TRUPACT-II is not vented, exposure to the hazardous chemical component of the TRU waste would not occur during routine transportation. Radiological risks to the public were calculated based on a full range of transportation accident scenarios and their probabilities of occurrence. A "bounding case" accident involving TRUPACT-II containers has been developed for completeness and to provide an upper-bound assessment of impacts. Evaluation of this accident provides maximum estimates of radiological and hazardous chemical risks (SEIS Subsections 5.2.2.1 and 5.2.2.2, respectively).

This assessment also addresses the risks of traffic accidents and vehicle emissions associated with the transportation of TRU waste to the WIPP. Data used in this analysis were obtained from several sources. Risks related to vehicle emissions were estimated for rail and truck from the number of miles traveled to the WIPP. During preparation of this SEIS, DOE requested state-specific data from 23 states that would be affected by TRU waste transportation. The following information was requested: total miles traveled; the number of accidents involving property damage, injuries, and fatalities and other information along the preferred shipping routes. Data were also requested concerning road segments of concern. State-specific data received were used in the impact assessments presented in SEIS Subsection 5.2.2.3 and are summarized in SEIS Appendix D.

5.2.2.1 Radiological Risk Assessment for Transportation. Radiological risks to occupationally exposed transportation workers (e.g., truck drivers, train operators), the general public, and the environment are assessed along transportation corridors from the generator and storage facilities to the WIPP. The assessment utilizes information on radiological characteristics of TRU waste as discussed in SEIS Appendix B. Radiological exposures potentially received by the public from routine transportation and from transportation accidents are provided below.

This SEIS provides risk estimates developed in response to more complete characterization of the TRU waste inventory, changes in the transportation routes and modes, and modifications to the dose assessment methodology from that assumed or employed in the FEIS.

The FEIS reported transportation impacts in terms of a radiation dose to an individual or population. Dose commitments were calculated for the whole body, lungs, and bone. The SEIS expresses radiation exposure in terms of committed effective dose equivalent and risk in terms of excess lifetime cancer risk. In both instances, the dose considered is that which occurs over the 50-year period following exposure. Direct comparisons of doses and risks reported in the FEIS to those reported in this SEIS cannot be made because of the differences in the assessment methodologies and the method of expressing dose. The SEIS estimates are based on updated knowledge of the wastes and improved assessment models and provide a more current estimate of transportation risks.

RADTRAN, a computer code (see SEIS Appendix D), was used in the FEIS to estimate radiation doses associated with normal or "routine" transportation of TRU waste to the WIPP. The FEIS used a modified version of the computer code AIRDOS-II (Moore, 1977) to calculate radiation doses for specific transportation accident scenarios. A specific, "most conservative" accident scenario was developed to represent an upper bound for an accident-induced release during waste transport. AIRDOS-II was then used to compute dose consequences to the public, assuming stable meteorological conditions to maximize the resulting dose consequences. The accident analysis results were reported as dose consequences to an individual and various population groups. An estimate was also made of the likelihood of such accidents.

In this SEIS, the radiological risks of transportation have been assessed using a modification of RADTRAN, a more recent version of the RADTRAN code that considers routine and accident situations. As discussed in Appendix D, the RADTRAN model has also been previously used and accepted by the Nuclear Regulatory Commission (NRC, 1977) and the Department of Energy (DOE, 1980).

In the RADTRAN models, risks are not based on specific accidents but on the likelihood and consequence of accidents of various severities, with more severe accidents having a higher release fraction (i.e., amount of wastes that are released to the environment) but lower probability of occurrence. The fractions of material released vary as a function of accident severity category. The model provides a probability weighted estimate of cumulative risk rather than specific dose calculations for individual accident scenarios. Further discussion of the risk calculation using the RADTRAN code is provided in SEIS Appendix D.3.

Even though accidents of different severity categories are already included in the RADTRAN analysis, a specific "bounding case" transportation accident scenario has been developed for the SEIS. The impact analysis was conducted to provide an upper-bound impact that could occur as a result of a severe accident involving truck transport of TRUPACT-II containers. The scenario was separately analyzed using the RADTRAN code.

The FEIS analysis assumed that 25 percent of the TRU waste would be shipped to the WIPP by truck and 75 percent by rail. In this SEIS, even though the preferred transport mode is truck, rail transportation impacts are analyzed in the event rail is utilized in the future. Therefore, this SEIS analyzes two cumulative transportation scenarios: 1) a 100 percent truck, and 2) a maximum rail transport case for waste transport from the generator and storage facilities. The maximum rail transport scenario consists of rail transport from eight of the 10 generator and storage facilities and truck transport from the two facilities (Nevada Test Site and Los Alamos National Laboratory) that do not currently have rail access. These two scenarios are projected to bound potential transportation impacts.

Routine Exposures from Transportation Activities. As discussed above, the FEIS used the RADTRAN code to estimate the radiation doses associated with incident free (routine) transportation of TRU waste to the WIPP. This SEIS uses a modification of the RADTRAN code to calculate routine doses to transportation workers, including truck drivers, and to members of the public on and along the route during transport and stops. Tables D.3.5, D.3.6, and D.3.7 in Appendix D.3 summarize key input parameters for the RADTRAN code. In general, risk assessment methodologies and waste characterization data have improved since publication of the FEIS, and provide more representative estimates than the FEIS analyses.

The only potential radiation exposure during routine transportation activities will be from direct radiation which penetrates the TRUPACT-II container. Direct radiation exposures to truck drivers, to members of the public driving alongside a waste shipment, to the roadside population, and to people in the parking lots where stops are made, are estimated. Table 5.5 provides the potential number of shipments from each location to the WIPP and the radiological exposure associated with shipments for the Proposed Action.

TABLE 5.5 Projected TRU-waste shipments and radiological exposure from waste shipments to the WIPP[a]

Facility	CH-waste							
	Total shipments[b]		Incident free Exposures per shipment[c] (person-rem)				Accidents Exposures per shipment (person-rem)	
			Truck		Rail		Truck	Rail
	100% Truck	Maximum Rail	Occupational	Public	Occupational	Public	Public	Public
Idaho National Engineering Laboratory	6162	3081	5.0×10^{-2}	2.0×10^{-2}	2.9×10^{-4}	3.0×10^{-2}	7.9×10^{-4}	5.7×10^{-4}
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]10^{-4}	2.0×10^{-2}	2.0×10^{-4}	1.9×10^{-4}
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]10^{-4}	4.0×10^{-2}	5.6×10^{-4}	9.5×10^{-4}
Savannah River Plant	3116	[illegible]	[illegible]	[illegible]	[illegible]10^{-4}	1.2×10^{-1}	4.2×10^{-2}	4.0×10^{-2}
Los Alamos National Laboratory[e]	2703	---	3.0×10^{-2}	1.0×10^{-2}	---	---	1.2×10^{-3}	---
Oak Ridge National Laboratory	286	143	1.3×10^{-1}	2.1×10^{-1}	2.1×10^{-3}	2.0×10^{-1}	5.9×10^{-3}	5.7×10^{-3}
Nevada Test Site[e]	121	---	5.0×10^{-2}	2.0×10^{-2}	---	---	8.9×10^{-6}	---
Argonne National Laboratory - East	16	8	1.3×10^{-1}	1.4×10^{-1}	1.8×10^{-3}	1.9×10^{-1}	4.9×10^{-4}	3.5×10^{-4}
Lawrence Livermore National Laboratory	1093	547	2.0×10^{-2}	1.0×10^{-2}	1.2×10^{-4}	2.0×10^{-2}	2.1×10^{-3}	3.3×10^{-3}
Mound Plant	169	85	2.0×10^{-2}	1.0×10^{-2}	1.1×10^{-4}	1.0×10^{-2}	6.2×10^{-7}	5.4×10^{-7}
TOTAL	26191	14509						

5	5-17	Table 5.5	9.5×10^{-4} in the far right, rail column, third down, should read 9.4×10^{-4}.

In this SEIS, the radiological risks of transportation have been assessed using a modification of RADTRAN, a more recent version of the RADTRAN code that considers routine and accident situations. As discussed in Appendix D, the RADTRAN model has also been previously used and accepted by the Nuclear Regulatory Commission (NRC, 1977) and the Department of Energy (DOE, 1980).

In the RADTRAN models, risks are not based on specific accidents but on the likelihood and consequence of accidents of various severities, with more severe accidents having a higher release fraction (i.e., amount of wastes that are released to the environment) but lower probability of occurrence. The fractions of material released vary as a function of accident severity category. The model provides a probability weighted estimate of cumulative risk rather than specific dose calculations for individual accident scenarios. Further discussion of the risk calculation using the RADTRAN code is provided in SEIS Appendix D.3.

Even though accidents of different severity categories are already included in the RADTRAN analysis, a specific "bounding case" transportation accident scenario has been developed for the SEIS. The impact analysis was conducted to provide an upper-bound impact that could occur as a result of a severe accident involving truck transport of TRUPACT-II containers. The scenario was separately analyzed using the RADTRAN code.

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Routine Exposures from Transportation Activities. As discussed above, the FEIS used the RADTRAN code to estimate the radiation doses associated with incident free (routine) transportation of TRU waste to the WIPP. This SEIS uses a modification of the RADTRAN code to calculate routine doses to transportation workers, including truck drivers, and to members of the public on and along the route during transport and stops. Tables D.3.5, D.3.6, and D.3.7 in Appendix D.3 summarize key input parameters for the RADTRAN code. In general, risk assessment methodologies and waste characterization data have improved since publication of the FEIS, and provide more representative estimates than the FEIS analyses.

The only potential radiation exposure during routine transportation activities will be from direct radiation which penetrates the TRUPACT-II container. Direct radiation exposures to truck drivers, to members of the public driving alongside a waste shipment, to the roadside population, and to people in the parking lots where stops are made, are estimated. Table 5.5 provides the potential number of shipments from each location to the WIPP and the radiological exposure associated with shipments for the Proposed Action.

TABLE 5.5 Projected TRU-waste shipments and radiological exposure from waste shipments to the WIPP[a]

	CH-waste							
	Total shipments[b]		Incident free Exposures per shipment[c] (person-rem)				Accidents Exposures per shipment (person-rem)	
			Truck		Rail		Truck	Rail
Facility	100% Truck	Maximum Rail	Occupational	Public	Occupational	Public	Public	Public
Idaho National Engineering Laboratory	6162	3081	5.0×10^{-2}	2.0×10^{-2}	2.9×10^{-4}	3.0×10^{-2}	7.9×10^{-4}	5.7×10^{-4}
ocky Flats Plant	8586	4293	4.0×10^{-2}	1.0×10^{-2}	2.7×10^{-4}	2.0×10^{-2}	2.0×10^{-4}	1.9×10^{-4}
anford Reservation	3939	1970	4.0×10^{-2}	2.0×10^{-2}	2.6×10^{-4}	4.0×10^{-2}	5.6×10^{-4}	9.5×10^{-4}
avannah River Plant	3116	1558	1.4×10^{-1}	7.0×10^{-2}	8.4×10^{-4}	1.2×10^{-1}	4.2×10^{-2}	4.0×10^{-2}
Los Alamos National Laboratory[e]	2703	---	3.0×10^{-2}	1.0×10^{-2}	---	---	1.2×10^{-3}	---
Oak Ridge National Laboratory	286	143	1.3×10^{-1}	2.1×10^{-1}	2.1×10^{-3}	2.0×10^{-1}	5.9×10^{-3}	5.7×10^{-3}
Nevada Test Site[e]	121	---	5.0×10^{-2}	2.0×10^{-2}	---	---	8.9×10^{-6}	---
Argonne National Laboratory - East	16	8	1.3×10^{-1}	1.4×10^{-1}	1.8×10^{-3}	1.9×10^{-1}	4.9×10^{-4}	3.5×10^{-4}
Lawrence Livermore National Laboratory	1093	547	2.0×10^{-2}	1.0×10^{-2}	1.2×10^{-4}	2.0×10^{-2}	2.1×10^{-3}	3.3×10^{-3}
Mound Plant	169	85	2.0×10^{-2}	1.0×10^{-2}	1.1×10^{-4}	1.0×10^{-2}	6.2×10^{-7}	5.4×10^{-7}
TOTAL	26191	14509						

5	5-18	Table 5.5 concluded	(1) Total of maximum rail column that reads 3958 should read 3997. (2) 8.0 x 10^{-1}, public exposures from truck transport from Idaho National Engineering Laboratory , should read 8.0 x 10^{-2}. (3) Footnote ^{e} should read "no rail transport; for calculation of total shipments, maximum rail, the number of truck shipments from facilities without rail access are included for CH waste and RH waste."

							Accidents Exposures per shipment (person-rem)	
					Rail		Truck	Rail
					)ational	Public	Public	Public
Idaho National Engineering Laboratory	187	94	1.0×10^{-1}	8.0×10^{-1}	1.3×10^{-3}	1.3×10^{-1}	1.8×10^{-6}	1.5×10^{-6}
Hanford Reservation	937	467	1.7×10^{-1}	3.3×10^{-1}	3.5×10^{-3}	2.9×10^{-1}	6.2×10^{-2}	6.3×10^{-2}
Los Alamos National Laboratory	39	---	3.0×10^{-2}	1.0×10^{-2}	----	----	4.4×10^{-6}	---
Oak Ridge National Laboratory	6781	3392	6.0×10^{-2}	4.0×10^{-2}	7.7×10^{-4}	7.0×10^{-2}	5.9×10^{-6}	6.4×10^{-6}
Argonne National Laboratory - East	9	5	5.0×10^{-2}	4.0×10^{-2}	5.5×10^{-4}	5.0×10^{-2}	6.4×10^{-6}	5.2×10^{-6}
TOTAL	7953	3958						

[a] Calculations based on three TRUPACT-IIs or one RH canister per truck and six TRUPACT-IIs or two RH canisters per railcar.

[b] Shipments calculated from drum volume of 0.2 m^3x(0.80)x14 drums/TRUPACT II.

[c] Risks per shipment are a function of the Transport Index (see Appendix D).

[d] Rail occupational risks include the impact of DOT inspection activities.

[e] No rail transport.

Annual cumulative exposures from waste transport based on projected inventory and current shipping plans for the Proposed Action are shown in Tables 5.6 and 5.7. (For ease of comparison, many tables provide information relative to the Proposed Action and the Alternative Action; in SEIS Subsection 5.2, the Proposed Action information is shaded.)

Table 5.8 presents the maximum exposure to any individual during routine transportation of CH and RH waste from each generator or storage facility to the WIPP for each alternative. The consequences of these exposures and their risks are presented below.

Transportation Accidents. As discussed above, the FEIS evaluated transportation accident impacts by specifying individual accident scenarios and their associated probability of occurrence. AIRDOS-II was then used to estimate radiation doses to the public. Accident scenarios were developed for small urban areas such as Carlsbad, New Mexico, and large urban areas such as Albuquerque, New Mexico. Quantitative estimates of the occupational radiation risk, such as to the involved truck driver or train crew, resulting from transportation accidents were not made in the FEIS or in this SEIS. Personnel involved in waste transport will receive extensive training in emergency response and will follow predetermined safety procedures. Such training will minimize occupational exposures during accidents; however, actual exposures will be dependent on the exact nature of the accident and cannot be readily estimated.

This SEIS includes estimates of the impacts of TRU waste transportation accidents on the public using a modification of the RADTRAN computer code. RADTRAN estimates cumulative, probability-weighted dose consequences to the population along the routes from generator and storage facilities to the WIPP. As discussed in SEIS Appendix D.3, RADTRAN does not incorporate specific accident scenarios. Instead, potential accidents are divided into eight severity classes, each of which has an associated probability of occurrence and release fraction. Release fractions are different for accidents involving damage due to fire versus crushing. It is assumed that two percent of potential accidents involving shipping containers result in fire (SEIS Appendix D.3). The probability of a given exposure to the population along the route is the product of accident frequency per mile, probability of occurrence of a given severity class accident, and the probability that the event will result in an impact or a fire. These probabilities are then summed over all severity classes.

The total population along the route is a sum of the products of the population density for rural, suburban, and urban zones, the length of the transportation route, and the fraction of travel through each of these zones. The population at risk due to external exposure rates for routine shipments is assumed to be that which resides within about 0.50 miles on either side of the transportation route. For accidents, the population at risk is modeled as the population in about a 1000 sq km in the downwind dispersion pattern from the postulated accident. These and other input parameters for the RADTRAN model are summarized in Table D.3.7. The annual probability-weighted population doses for the accidents during the Proposed Action are also presented in Table 5.6. Accident consequences were tabulated for 100 percent truck shipment and for maximum rail shipment of waste to the WIPP. Consequences of these radiation exposures are discussed below.

TABLE 5.5 Concluded

	RH-waste[d]							
	Total shipments		Incident free Exposures per shipment (person-rem)				Accidents Exposures per shipment (person-rem)	
			Truck		Rail		Truck	Rail
	100% Truck	Maximum Rail	Occupational	Public	Occupational	Public	Public	Public
Idaho National Engineering Laboratory	187	94	$1.0x10^{-1}$	$8.0x10^{-1}$	$1.3x10^{-3}$	$1.3x10^{-1}$	$1.8x10^{-6}$	$1.5x10^{-6}$
Hanford Reservation	937	467	$1.7x10^{-1}$	$3.3x10^{-1}$	$3.5x10^{-3}$	$2.9x10^{-1}$	$6.2x10^{-2}$	$6.3x10^{-2}$
Los Alamos National Laboratory	39	---	$3.0x10^{-2}$	$1.0x10^{-2}$	----	----	$4.4x10^{-6}$	----
Oak Ridge National Laboratory	6781	3392	$6.0x10^{-2}$	$4.0x10^{-2}$	$7.7x10^{-4}$	$7.0x10^{-2}$	$5.9x10^{-6}$	$6.4x10^{-6}$
Argonne National Laboratory - East	9	5	$5.0x10^{-2}$	$4.0x10^{-2}$	$5.5x10^{-4}$	$5.0x10^{-2}$	$6.4x10^{-6}$	$5.2x10^{-6}$
TOTAL	7953	3958						

[a] Calculations based on three TRUPACT-IIs or one RH canister per truck and six TRUPACT-IIs or two RH canisters per railcar.

[b] Shipments calculated from drum volume of 0.2 m^3x(0.80)x14 drums/TRUPACT II.

[c] Risks per shipment are a function of the Transport Index (see Appendix D).

[d] Rail occupational risks include the impact of DOT inspection activities.

[e] No rail transport.

Annual cumulative exposures from waste transport based on projected inventory and current shipping plans for the Proposed Action are shown in Tables 5.6 and 5.7. (For ease of comparison, many tables provide information relative to the Proposed Action and the Alternative Action; in SEIS Subsection 5.2, the Proposed Action information is shaded.)

Table 5.8 presents the maximum exposure to any individual during routine transportation of CH and RH waste from each generator or storage facility to the WIPP for each alternative. The consequences of these exposures and their risks are presented below.

Transportation Accidents. As discussed above, the FEIS evaluated transportation accident impacts by specifying individual accident scenarios and their associated probability of occurrence. AIRDOS-II was then used to estimate radiation doses to the public. Accident scenarios were developed for small urban areas such as Carlsbad, New Mexico, and large urban areas such as Albuquerque, New Mexico. Quantitative estimates of the occupational radiation risk, such as to the involved truck driver or train crew, resulting from transportation accidents were not made in the FEIS or in this SEIS. Personnel involved in waste transport will receive extensive training in emergency response and will follow predetermined safety procedures. Such training will minimize occupational exposures during accidents; however, actual exposures will be dependent on the exact nature of the accident and cannot be readily estimated.

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The total population along the route is a sum of the products of the population density for rural, suburban, and urban zones, the length of the transportation route, and the fraction of travel through each of these zones. The population at risk due to external exposure rates for routine shipments is assumed to be that which resides within about 0.50 miles on either side of the transportation route. For accidents, the population at risk is modeled as the population in about a 1000 sq km in the downwind dispersion pattern from the postulated accident. These and other input parameters for the RADTRAN model are summarized in Table D.3.7. The annual probability-weighted population doses for the accidents during the Proposed Action are also presented in Table 5.6. Accident consequences were tabulated for 100 percent truck shipment and for maximum rail shipment of waste to the WIPP. Consequences of these radiation exposures are discussed below.

TABLE 5.6 Annual cumulative radiological exposures (person-rem) for CH-TRU Proposed Action waste shipments to the WIPP

	Proposed Action		Proposed Action				Alternative Action			
	5 Yr Test Phase[a]		20 Yr Disposal Phase				20 Yr Disposal Phase			
	100% Truck		100% Truck		Maximum Rail		100% Truck		Maximum Rail	
Facility	Occupational[b]	Public[c]	Occupational	Public	Occupational	Public	Occupational	Public	Occupational	Public
Idaho National Engineering Laboratory										
Normal	6.2×10^{0}	2.4×10^{0}	1.4×10^{1}	5.5×10^{0}	4.0×10^{-2}	4.2×10^{0}	1.6×10^{1}	6.0×10^{0}	4.4×10^{-2}	4.6×10^{0}
Accident		9.8×10^{-2}		2.2×10^{-1}		8.0×10^{-2}		2.4×10^{-1}		8.5×10^{-2}
Rocky Flats Plant										
Normal	6.8×10^{0}	1.7×10^{0}	1.6×10^{1}	3.8×10^{0}	5.0×10^{-2}	3.8×10^{0}	1.7×10^{1}	4.3×10^{0}	6.0×10^{-2}	4.3×10^{0}
Accident		3.4×10^{-2}		7.5×10^{-2}		3.6×10^{-2}		8.5×10^{-2}		4.1×10^{-2}
Hanford Reservation										
Normal	3.2×10^{0}	1.6×10^{0}	7.0×10^{0}	3.6×10^{0}	2.4×10^{-2}	3.6×10^{0}	8.0×10^{0}	4.0×10^{0}	2.6×10^{-2}	4.0×10^{0}
Accident		4.4×10^{-2}		1.0×10^{-1}		8.5×10^{-2}		1.1×10^{-1}		8.5×10^{-2}
Savannah River Plant										
Normal	8.8×10^{0}	4.4×10^{0}	2.0×10^{1}	1.0×10^{1}	6.0×10^{-2}	8.5×10^{0}	2.2×10^{1}	1.1×10^{1}	6.5×10^{-2}	9.5×10^{0}
Accident		2.6×10^{0}		6.0×10^{0}		2.8×10^{0}		6.5×10^{0}		3.1×10^{0}
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	4.2×10^{0}	1.4×10^{0}	4.0×10^{0}	1.4×10^{0}
[illegible]		[illegible]		[illegible]		[illegible]		1.6×10^{-1}		1.6×10^{-1}
[illegible]										
Normal	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	1.8×10^{0}	3.0×10^{0}	1.5×10^{-2}	1.4×10^{0}
Accident		3.4×10^{-2}		7.5×10^{-2}		3.6×10^{-2}		8.5×10^{-2}		4.0×10^{-2}
Nevada Test Site[d]										
Normal	1.2×10^{-1}	4.8×10^{-2}	2.8×10^{-1}	1.1×10^{-1}	2.8×10^{-1}	1.1×10^{-1}	3.0×10^{-1}	1.2×10^{-1}	3.0×10^{-1}	1.2×10^{-1}
Accident		2.2×10^{-5}		4.8×10^{-5}		4.8×10^{-5}		5.5×10^{-5}		5.5×10^{-5}

5 5-20 Table 5.6 In Alternative Action 20-yr Disposal Phase, 100% truck, occupational column for Los Alamos National Laboratory - normal: 4.2 x 10^{0} should read 4.1 x 10^{0}.

TABLE 5.6 Concluded

	Proposed Action 5 Yr Test Phase		Proposed Action 20 Yr Disposal Phase				Alternative Action 20 Yr Disposal Phase			
	100% Truck		100% Truck		Maximum Rail		100% Truck		Maximum Rail	
	Occupational[b]	Public[c]	Occupational	Public	Occupational	Public	Occupational	Public	Occupational	Public
Argonne National Laboratory - East										
Normal	5.2×10^{-2}	5.6×10^{-2}	9.0×10^{-2}	1.1×10^{-1}	6.5×10^{-4}	6.5×10^{-2}	1.0×10^{-1}	1.1×10^{-1}	7.0×10^{-4}	7.5×10^{-2}
Accident		1.9×10^{-4}		3.4×10^{-4}		1.2×10^{-4}		3.9×10^{-4}		1.1×10^{-4}
Lawrence Livermore National Laboratory										
Normal	4.4×10^{-1}	2.2×10^{-1}	1.0×10^{0}	4.9×10^{-1}	3.0×10^{-3}	4.9×10^{-1}	1.1×10^{0}	5.5×10^{-1}	3.3×10^{-3}	5.5×10^{-1}
Accident		4.6×10^{-2}		1.0×10^{-1}		8.0×10^{-2}		1.2×10^{-1}		9.5×10^{-2}
Mound Plant										
Normal	6.8×10^{-2}	3.4×10^{-2}	1.5×10^{-1}	7.5×10^{-2}	1.7×10^{-4}	3.8×10^{-2}	1.7×10^{-1}	8.5×10^{-2}	4.7×10^{-4}	4.3×10^{-2}
Accident		2.0×10^{-6}		4.7×10^{-6}		2.0×10^{-6}		5.0×10^{-6}		2.3×10^{-1}
Cumulative Risk										
Normal	2.8×10^{1}	1.2×10^{1}	6.4×10^{1}	2.8×10^{1}	4.1×10^{0}	2.3×10^{1}	7.1×10^{1}	3.1×10^{1}	4.5×10^{0}	2.6×10^{1}
Accident	—	2.9×10^{0}	—	6.7×10^{0}	—	3.3×10^{0}	—	7.3×10^{0}	—	3.6×10^{0}
TOTAL	2.8×10^{1}	1.5×10^{1}	6.4×10^{1}	3.5×10^{1}	4.1×10^{0}	2.6×10^{1}	7.1×10^{1}	3.8×10^{1}	4.5×10^{0}	3.0×10^{1}

[a] Assumes 10% of shipments from all generator sites completed during Test Phase; all shipments are made by truck.

[b] Occupational Population is all the transportation crews.

[c] Nonoccupational population.

[d] Waste shipments limited to truck mode. Rail risks are the same as truck risks.

TABLE 5.6 Annual cumulative radiological exposures (person-rem) for CH-TRU Proposed Action waste shipments to the WIPP

	Proposed Action 5 Yr Test Phase[a]		Proposed Action 20 Yr Disposal Phase				Alternative Action 20 Yr Disposal Phase			
	100% Truck		100% Truck		Maximum Rail		100% Truck		Maximum Rail	
Facility	Occupational[b]	Public[c]	Occupational	Public	Occupational	Public	Occupational	Public	Occupational	Public
Idaho National Engineering Laboratory										
Normal	$6.2\text{x}10^{0}$	$2.4\text{x}10^{0}$	$1.4\text{x}10^{1}$	$5.5\text{x}10^{0}$	$4.0\text{x}10^{-2}$	$4.2\text{x}10^{0}$	$1.6\text{x}10^{1}$	$6.0\text{x}10^{0}$	$4.4\text{x}10^{-2}$	$4.6\text{x}10^{0}$
Accident		$9.8\text{x}10^{-2}$		$2.2\text{x}10^{-1}$		$8.0\text{x}10^{-2}$		$2.4\text{x}10^{-1}$		$8.5\text{x}10^{-2}$
Rocky Flats Plant										
Normal	$6.8\text{x}10^{0}$	$1.7\text{x}10^{0}$	$1.6\text{x}10^{1}$	$3.8\text{x}10^{0}$	$5.0\text{x}10^{-2}$	$3.8\text{x}10^{0}$	$1.7\text{x}10^{1}$	$4.3\text{x}10^{0}$	$6.0\text{x}10^{-2}$	$4.3\text{x}10^{0}$
Accident		$3.4\text{x}10^{-2}$		$7.5\text{x}10^{-2}$		$3.6\text{x}10^{-2}$		$8.5\text{x}10^{-2}$		$4.1\text{x}10^{-2}$
Hanford Reservation										
Normal	$3.2\text{x}10^{0}$	$1.6\text{x}10^{0}$	$7.0\text{x}10^{0}$	$3.6\text{x}10^{0}$	$2.4\text{x}10^{-2}$	$3.6\text{x}10^{0}$	$8.0\text{x}10^{0}$	$4.0\text{x}10^{0}$	$2.6\text{x}10^{-2}$	$4.0\text{x}10^{0}$
Accident		$4.4\text{x}10^{-2}$		$1.0\text{x}10^{-1}$		$8.5\text{x}10^{-2}$		$1.1\text{x}10^{-1}$		$8.5\text{x}10^{-2}$
Savannah River Plant										
Normal	$8.8\text{x}10^{0}$	$4.4\text{x}10^{0}$	$2.0\text{x}10^{1}$	$1.0\text{x}10^{1}$	$6.0\text{x}10^{-2}$	$8.5\text{x}10^{0}$	$2.2\text{x}10^{1}$	$1.1\text{x}10^{1}$	$6.5\text{x}10^{-2}$	$9.5\text{x}10^{0}$
Accident		$2.6\text{x}10^{0}$		$6.0\text{x}10^{0}$		$2.8\text{x}10^{0}$		$6.5\text{x}10^{0}$		$3.1\text{x}10^{0}$
Los Alamos National Laboratory[d]										
Normal	$1.6\text{x}10^{0}$	$5.4\text{x}10^{-1}$	$3.6\text{x}10^{0}$	$1.2\text{x}10^{0}$	$3.6\text{x}10^{0}$	$1.2\text{x}10^{0}$	$4.2\text{x}10^{0}$	$1.4\text{x}10^{0}$	$4.0\text{x}10^{0}$	$1.4\text{x}10^{0}$
Accident		$6.6\text{x}10^{-2}$		$1.0\text{x}10^{-1}$		$1.4\text{x}10^{-1}$		$1.6\text{x}10^{-1}$		$1.6\text{x}10^{-1}$
Oak Ridge National Laboratory										
Normal	$7.6\text{x}10^{-1}$	$1.2\text{x}10^{0}$	$1.6\text{x}10^{0}$	$2.7\text{x}10^{0}$	$1.4\text{x}10^{-2}$	$1.4\text{x}10^{0}$	$1.8\text{x}10^{0}$	$3.0\text{x}10^{0}$	$1.5\text{x}10^{-2}$	$1.4\text{x}10^{0}$
Accident		$3.4\text{x}10^{-2}$		$7.5\text{x}10^{-2}$		$3.6\text{x}10^{-2}$		$8.5\text{x}10^{-2}$		$4.0\text{x}10^{-2}$
Nevada Test Site[d]										
Normal	$1.2\text{x}10^{-1}$	$4.8\text{x}10^{-2}$	$2.8\text{x}10^{-1}$	$1.1\text{x}10^{-1}$	$2.8\text{x}10^{-1}$	$1.1\text{x}10^{-1}$	$3.0\text{x}10^{-1}$	$1.2\text{x}10^{-1}$	$3.0\text{x}10^{-1}$	$1.2\text{x}10^{-1}$
Accident		$2.2\text{x}10^{-5}$		$4.8\text{x}10^{-5}$		$4.8\text{x}10^{-5}$		$5.5\text{x}10^{-5}$		$5.5\text{x}10^{-5}$

TABLE 5.6 Concluded

	Proposed Action 5 Yr Test Phase		Proposed Action 20 Yr Disposal Phase				Alternative Action 20 Yr Disposal Phase			
	100% Truck		100% Truck		Maximum Rail		100% Truck		Maximum Rail	
	Occupational[b]	Public[c]	Occupational	Public	Occupational	Public	Occupational	Public	Occupational	Public
Argonne National Laboratory - East										
Normal	5.2×10^{-2}	5.6×10^{-2}	9.0×10^{-2}	1.1×10^{-1}	6.5×10^{-4}	6.5×10^{-2}	1.0×10^{-1}	1.1×10^{-1}	7.0×10^{-4}	7.5×10^{-2}
Accident		1.9×10^{-4}		3.4×10^{-4}		1.2×10^{-4}		3.9×10^{-4}		1.1×10^{-4}
Lawrence Livermore National Laboratory										
Normal	4.4×10^{-1}	2.2×10^{-1}	1.0×10^{0}	4.9×10^{-1}	3.0×10^{-3}	4.9×10^{-1}	1.1×10^{0}	5.5×10^{-1}	3.3×10^{-3}	5.5×10^{-1}
Accident		4.6×10^{-2}		1.0×10^{-1}		8.0×10^{-2}		1.2×10^{-1}		9.5×10^{-2}
Mound Plant										
Normal	6.8×10^{-2}	3.4×10^{-2}	1.5×10^{-1}	7.5×10^{-2}	1.7×10^{-4}	3.8×10^{-2}	1.7×10^{-1}	8.5×10^{-2}	4.7×10^{-4}	4.3×10^{-2}
Accident		2.0×10^{-6}		4.7×10^{-6}		2.0×10^{-6}		5.0×10^{-6}		2.3×10^{-1}
Cumulative Risk										
Normal	2.8×10^{1}	1.2×10^{1}	6.4×10^{1}	2.8×10^{1}	4.1×10^{0}	2.3×10^{1}	7.1×10^{1}	3.1×10^{1}	4.5×10^{0}	2.6×10^{1}
Accident	---	2.9×10^{0}	---	6.7×10^{0}	---	3.3×10^{0}	---	7.3×10^{0}	---	3.6×10^{0}
TOTAL	2.8×10^{1}	1.5×10^{1}	6.4×10^{1}	3.5×10^{1}	4.1×10^{0}	2.6×10^{1}	7.1×10^{1}	3.8×10^{1}	4.5×10^{0}	3.0×10^{1}

[a] Assumes 10% of shipments from all generator sites completed during Test Phase; all shipments are made by truck.

[b] Occupational Population is all the transportation crews.

[c] Nonoccupational population.

[d] Waste shipments limited to truck mode. Rail risks are the same as truck risks.

TABLE 5.7 Annual cumulative radiological exposures (person-rem) for RH-TRU Proposed Action waste shipments to the WIPP

	Proposed action[a] 20 Yr Disposal Phase				Alternative Action 20 Yr Disposal Phase			
	100% Truck		Maximum Rail		100% Truck		Maximum Rail	
Facility	Occupational[b]	Public[c]	Occupational	Public	Occupational	Public	Occupational	Public
Idaho National Engineering Laboratory								
Normal	9.5×10^{-1}	7.5×10^{-1}	6.0×10^{-3}	6.0×10^{-1}	9.5×10^{-1}	7.5×10^{-1}	6.0×10^{-3}	6.0×10^{-1}
Accident		1.7×10^{-5}		7.0×10^{-6}		1.7×10^{-5}		7.0×10^{-6}
Hanford Reservation								
Normal	8.0×10^{0}	1.6×10^{1}	8.0×10^{-2}	7.0×10^{0}	8.0×10^{0}	1.6×10^{1}	8.0×10^{-2}	7.0×10^{0}
Accident		2.9×10^{0}		1.4×10^{0}		2.9×10^{0}		1.4×10^{0}
Los Alamos National Laboratory								
Normal	6.0×10^{-2}	2.0×10^{-2}	6.0×10^{-2}	2.0×10^{-2}	6.0×10^{-2}	2.0×10^{-2}	6.0×10^{-2}	2.0×10^{-2}
Accident		8.5×10^{-6}		8.5×10^{-6}		8.5×10^{-6}		8.5×10^{-6}
Oak Ridge National Laboratory[b]								
Normal	2.1×10^{1}	1.4×10^{1}	1.3×10^{-1}	1.2×10^{1}	2.1×10^{1}	1.4×10^{1}	1.3×10^{-1}	1.2×10^{1}
Accident		2.0×10^{-3}		2.8×10^{-4}		2.0×10^{-3}		2.8×10^{-4}
Argonne National Laboratory - East								
Normal	2.2×10^{-2}	1.8×10^{-2}	1.3×10^{-4}	1.2×10^{-2}	2.2×10^{-2}	1.8×10^{-2}	1.3×10^{-4}	1.2×10^{-2}
Accident		2.9×10^{-6}		1.3×10^{-6}		2.9×10^{-6}		1.3×10^{-6}
Cumulative Risk								
Normal	3.0×10^{1}	3.1×10^{1}	2.8×10^{-1}	2.0×10^{1}	3.0×10^{1}	3.1×10^{1}	2.8×10^{-1}	2.0×10^{1}
Accident	—	2.9×10^{0}	—	1.4×10^{0}		2.9×10^{0}		1.4×10^{0}
TOTAL	3.0×10^{1}	3.4×10^{1}	2.8×10^{-1}	2.1×10^{1}	3.0×10^{1}	3.4×10^{1}	2.8×10^{-1}	2.1×10^{1}

[a] At the time of preparation of this SEIS, no RH wastes were assumed during the Test Phase -- therefore, postulated exposures for RH waste shipments are the same for either scenario.

[b] Occupational population is the total transportation crews.

[c] Nonoccupational population.

[d] To increase projected TRU waste volumes to WIPP maximum capacity, additional volumes of RH-TRU waste than known at present were assumed to originate at Oak Ridge National Laboratory.

TABLE 5.8 Hypothetical maximum exposure (rem) to any individual from incident-free Proposed Action transportation to the WIPP[a]

	Proposed Action				Alternative Action			
	100% Truck		Maximum Rail		100% Truck		Maximum Rail	
Shipment Origin Site	CH	RH	CH	RH	CH	RH	CH	RH
Idaho National Engineering Laboratory	2.3×10^{-4}	2.4×10^{-5}	2.2×10^{-4}	2.5×10^{-5}	2.3×10^{-4}	2.4×10^{-5}	2.2×10^{-4}	2.5×10^{-5}
Rocky Flats Plant	4.7×10^{-4}	---	4.7×10^{-4}	---	4.7×10^{-4}	---	4.7×10^{-4}	---
Hanford Reservation	1.0×10^{-4}	4.0×10^{-4}	1.0×10^{-4}	4.0×10^{-4}	1.0×10^{-4}	4.0×10^{-4}	1.0×10^{-4}	4.0×10^{-4}
Savannah River Plant	3.1×10^{-4}	---	3.1×10^{-4}	---	3.1×10^{-4}	---	3.1×10^{-4}	---
Los Alamos National Laboratory[b]	4.0×10^{-4}	9.4×10^{-6}	4.0×10^{-4}	9.4×10^{-6}	4.0×10^{-4}	9.4×10^{-6}	4.0×10^{-4}	9.4×10^{-6}
Oak Ridge National Laboratory	1.1×10^{-4}	5.8×10^{-4}	1.1×10^{-4}	5.8×10^{-4}	1.1×10^{-4}	5.8×10^{-4}	1.1×10^{-4}	5.8×10^{-4}
Nevada Test Site[b]	5.3×10^{-6}	---	5.3×10^{-6}	---	5.3×10^{-6}	---	5.3×10^{-6}	---
Argonne National Laboratory - East	4.3×10^{-6}	6.1×10^{-7}	4.4×10^{-6}	8.0×10^{-7}	4.3×10^{-6}	6.1×10^{-7}	4.4×10^{-6}	8.0×10^{-7}
Lawrence Livermore National Laboratory	1.6×10^{-5}	---	1.6×10^{-5}	---	1.6×10^{-5}	---	1.6×10^{-5}	---
					10^{-6}	---	2.6×10^{-6}	---
					10^{-3}	1.0×10^{-3}	1.6×10^{-3}	1.0×10^{-3}

5	5-23	Table 5.8	In Proposed Action, RH maximum rail column total: 1.0×10^{-3} should read 1.1×10^{-3}.
5	5-23	Table 5.8	In Alternative Action, RH Maximum Rail column total: 1.0×10^{-3} should read 1.1×10^{-3}.

TABLE 5.7 Annual cumulative radiological exposures (person-rem) for RH-TRU Proposed Action waste shipments to the WIPP

	Proposed action[a] 20 Yr Disposal Phase				Alternative Action 20 Yr Disposal Phase			
	100% Truck		Maximum Rail		100% Truck		Maximum Rail	
Facility	Occupational[b]	Public[c]	Occupational	Public	Occupational	Public	Occupational	Public
Idaho National Engineering Laboratory								
Normal	9.5×10^{-1}	7.5×10^{-1}	6.0×10^{-3}	6.0×10^{-1}	9.5×10^{-1}	7.5×10^{-1}	6.0×10^{-3}	6.0×10^{-1}
Accident		1.7×10^{-5}		7.0×10^{-6}		1.7×10^{-5}		7.0×10^{-6}
Hanford Reservation								
Normal	8.0×10^{0}	1.6×10^{1}	8.0×10^{-2}	7.0×10^{0}	8.0×10^{0}	1.6×10^{1}	8.0×10^{-2}	7.0×10^{0}
Accident		2.9×10^{0}		1.4×10^{0}		2.9×10^{0}		1.4×10^{0}
Los Alamos National Laboratory								
Normal	6.0×10^{-2}	2.0×10^{-2}	6.0×10^{-2}	2.0×10^{-2}	6.0×10^{-2}	2.0×10^{-2}	6.0×10^{-2}	2.0×10^{-2}
Accident		8.5×10^{-6}		8.5×10^{-6}		8.5×10^{-6}		8.5×10^{-6}
Oak Ridge National Laboratory[b]								
Normal	2.1×10^{1}	1.4×10^{1}	1.3×10^{-1}	1.2×10^{1}	2.1×10^{1}	1.4×10^{1}	1.3×10^{-1}	1.2×10^{1}
Accident		2.0×10^{-3}		2.8×10^{-4}		2.0×10^{-3}		2.8×10^{-4}
Argonne National Laboratory - East								
Normal	2.2×10^{-2}	1.8×10^{-2}	1.3×10^{-4}	1.2×10^{-2}	2.2×10^{-2}	1.8×10^{-2}	1.3×10^{-4}	1.2×10^{-2}
Accident		2.9×10^{-6}		1.3×10^{-6}		2.9×10^{-6}		1.3×10^{-6}
Cumulative Risk								
Normal	3.0×10^{1}	3.1×10^{1}	2.8×10^{-1}	2.0×10^{1}	3.0×10^{1}	3.1×10^{1}	2.8×10^{-1}	2.0×10^{1}
Accident	—	2.9×10^{0}	—	1.4×10^{0}		2.9×10^{0}		1.4×10^{0}
TOTAL	3.0×10^{1}	3.4×10^{1}	2.8×10^{-1}	2.1×10^{1}	3.0×10^{1}	3.4×10^{1}	2.8×10^{-1}	2.1×10^{1}

[a] At the time of preparation of this SEIS, no RH wastes were assumed during the Test Phase -- therefore, postulated exposures for RH waste shipments are the same for either scenario.

[b] Occupational population is the total transportation crews.

[c] Nonoccupational population.

[d] To increase projected TRU waste volumes to WIPP maximum capacity, additional volumes of RH-TRU waste than known at present were assumed to originate at Oak Ridge National Laboratory.

TABLE 5.8 Hypothetical maximum exposure (rem) to any individual from incident-free Proposed Action transportation to the WIPP[a]

	Proposed Action				Alternative Action			
	100% Truck		Maximum Rail		100% Truck		Maximum Rail	
Shipment Origin Site	CH	RH	CH	RH	CH	RH	CH	RH
Idaho National Engineering Laboratory	2.3×10^{-4}	2.4×10^{-5}	2.2×10^{-4}	2.5×10^{-5}	2.3×10^{-4}	2.4×10^{-5}	2.2×10^{-4}	2.5×10^{-5}
Rocky Flats Plant	4.7×10^{-4}	---	4.7×10^{-4}	---	4.7×10^{-4}	---	4.7×10^{-4}	---
Hanford Reservation	1.0×10^{-4}	4.0×10^{-4}	1.0×10^{-4}	4.0×10^{-4}	1.0×10^{-4}	4.0×10^{-4}	1.0×10^{-4}	4.0×10^{-4}
Savannah River Plant	3.1×10^{-4}	---	3.1×10^{-4}	---	3.1×10^{-4}	---	3.1×10^{-4}	---
Los Alamos National Laboratory[b]	4.0×10^{-4}	9.4×10^{-6}	4.0×10^{-4}	9.4×10^{-6}	4.0×10^{-4}	9.4×10^{-6}	4.0×10^{-4}	9.4×10^{-6}
Oak Ridge National Laboratory	1.1×10^{-4}	5.8×10^{-4}	1.1×10^{-4}	5.8×10^{-4}	1.1×10^{-4}	5.8×10^{-4}	1.1×10^{-4}	5.8×10^{-4}
Nevada Test Site[b]	5.3×10^{-6}	---	5.3×10^{-6}	---	5.3×10^{-6}	---	5.3×10^{-6}	---
Argonne National Laboratory - East	4.3×10^{-6}	6.1×10^{-7}	4.4×10^{-6}	8.0×10^{-7}	4.3×10^{-6}	6.1×10^{-7}	4.4×10^{-6}	8.0×10^{-7}
Lawrence Livermore National Laboratory	1.6×10^{-5}	---	1.6×10^{-5}	---	1.6×10^{-5}	---	1.6×10^{-5}	---
Mound Plant	2.5×10^{-6}	---	2.6×10^{-6}	---	2.5×10^{-6}	---	2.6×10^{-6}	---
TOTAL	1.6×10^{-3}	1.0×10^{-3}	1.6×10^{-3}	1.0×10^{-3}	1.6×10^{-3}	1.0×10^{-3}	1.6×10^{-3}	1.0×10^{-3}

[a] Hypothetical individual is assumed to be exposed to all shipments of waste to the WIPP.

[b] Waste shipments are limited to the truck mode. Rail risks are thus the same as truck risks.

As discussed earlier, a "bounding case" accident scenario was developed for this SEIS. The scenario was used to calculate the impact of a very severe accident in the higher populated areas. The "bounding case" accident scenario involved a truck shipment carrying three TRUPACT-II containers. The shipment was postulated to be involved in the highest severity category accident (i.e., category eight). Each TRUPACT-II was assumed to contain 14 55-gal Type A drums carrying CH TRU waste typical of that generated by the Rocky Flats Plant.

The TRUPACT-IIs were assumed to be equally breached (major breaches are not credible) and subsequently engulfed in a fire for at least two hours; (it is estimated that at least 17,000 gallons of fuel would be required to provide sufficient fuel to sustain a two-hour fire). External air/oxygen sources were assumed to be limited since a major breach of any of the Type B TRUPACT-II transporters is not credible (i.e., internal combustion was limited). Radioactive contamination was assumed to be evenly distributed throughout the waste volume and 0.02 percent of the hazardous and radioactive particulate materials were postulated to be released in a respirable form (less than 10 micron particle size). The accident was assumed to occur in an urbanized portion of a large metropolitan area during a period with very stable atmospheric meteorological conditions. Stable meteorological conditions limit dispersion or breakup of the plume and tend to maximize radiation doses and hazardous chemical concentration.

The RADTRAN computer model (SEIS Appendix D.3) was used to evaluate the radiological consequences of the accident scenario. The assessment estimates a collective population effective 50-year dose commitment of 1,240 person-rem and a maximum individual committed effective dose equivalent of 0.49 rem. The average individual committed effective dose equivalent is 0.08 rem.

As stated earlier, accidents of all severity categories, including category 8, are already included in the risk estimates provided in this subsection. The "bounding case" accident has an extremely low likelihood of occurring. The probability of breaching three TRUPACT-IIs (which are specifically constructed to withstand severe accidents) and engulfing them in a two-hour fire (requiring the fuel equivalent of two fully loaded fuel transports) in an urban area during adverse meteorological conditions is extremely small. The actual risk posed by this accident therefore is small since risk is dependent on the probability and the consequences of the event. Additional conservatism in the analysis included use of average population densities higher than currently exist along most transportation corridors, including Atlanta, Georgia; Denver, Colorado; and Albuquerque, New Mexico.

Human Health and Environmental Consequences of Radiological Releases. Estimated releases of and consequent exposures to radioactive materials in the TRU wastes pose potential risks to human health and the environment. The FEIS calculated radiological exposures for human populations and discussed the potential health effects associated with those exposures. In this SEIS assessment, risks to human health are expressed as an increase in the risk of fatal cancers due to radiological exposures.

Radiation can affect human health by causing cancer, genetic disorders, and other health problems. The Committee on Biological Effects of Ionizing Radiation (BEIR) of the National Academy of Sciences has published a detailed review of available data on radiation-induced health effects (BEIR, 1980). This report (BEIR III) uses a variety of data and accepted methods to quantify the health impacts of low levels of radiation. Its estimates of health risk associated with radiation exposure have been used to quantify the possible radiation-induced health effects that might be caused by operation of the WIPP; these potential health effects are discussed below.

Cancer risk estimates for transuranics are based on human exposure studies of alpha-emitting radionuclides other than transuranics and on the results of animal exposure studies. The ICRP also provides risk estimates for radiation exposure in Publication 26. BEIR III risk estimates were used in this SEIS because 1) BEIR III is a more comprehensive evaluation of radiation-induced health effects and 2) BEIR III results in higher estimates of total health effects.

The BEIR III report identifies the following three categories of radiation-induced human health effects: 1) cancer, 2) genetic disorders, and 3) somatic effects other than cancer. The BEIR Committee believes that carcinomas are the most important effect of low-dose radiation. In this context, the term "low dose" refers to dose equivalents as high as a few rem per person per year. Natural background radiation ranges from 0.1 to 0.2 rem per person per year. Genetic effects of low-level radiation have been well documented and are addressed in detail in the BEIR III report. Somatic effects other than cancer include cataract induction and fertility impairment. The BEIR III report concludes that low-dose exposure of human populations does not increase the risk of somatic effects other than cancer and developmental changes in unborn children. The report also indicates that developmental changes in unborn children are probably not caused by radiation at or below natural background levels. For these reasons, only cancer and genetic disorders are considered in the analysis for this SEIS.

Cancer data from the Japanese survivors of nuclear detonations in World War II are used in most of the analyses in the BEIR III report. A major question addressed by the BEIR III report is how to extrapolate the cancer risks observed at the relatively high does rates down to the lower dose rates caused by most nuclear facilities. The BEIR III report adopted a parametric family of functions to accomplish this extrapolation. The linear model represents an upper limit or maximum risk; the linear-quadratic model, an intermediate or probable risk; and the quadratic model, a low limit or minimum risk. These functions have been suggested by the report for low-linear-energy-transfer (LET) radiation. This type of radiation includes gamma-, x-, and electron (beta particle) radiation. High-LET radiation includes alpha particles encountered in the decay of transuranic radionuclides. This type of radiation is associated with the majority of the WIPP radioactive releases. The BEIR III report suggests that for high-LET radiation, use of the linear model represents the best way to determine probable risk; therefore, the linear model was used. However, because its appropriateness for high-LET radiation has not been definitely established, it is possible that the potential number of fatal cancers associated with WIPP operations is lower than presented in this SEIS. This would be the case if either the linear-quadratic or quadratic model would be determined to be more appropriate for high-LET radiation than the linear model. Indeed, if the quadratic model were used, the number of potential fatal cancers could approach zero.

One characteristic of radiation-induced cancer is that it takes a long time to develop, a period referred to as the "latent period." Leukemia has a characteristically short latent period (less than 25 years), whereas other cancers can have latent periods as long as the life span of the individual. Because only about 40 years of cancer data have been collected on the survivors of nuclear detonations, the data do not account for all the cancers that might develop because of the resultant radiation. The following two projection models have been developed to account for these future cancer deaths: 1) the absolute-risk projection model, which assumes that the cancer rate (risk per year) observed since the nuclear detonations will continue throughout the life spans of those exposed; and 2) the relative-risk model, which assumes that the excess radiation-induced risk is proportional to the natural incidence of cancer with age. The relative-risk model results in cancer risk estimates greater than those predicted by the absolute model. However, the BEIR III report states that the absolute model is generally more applicable to most forms of cancer. The cancer risk estimates used in this SEIS represent an average of those calculated using the absolute-risk and relative-risk models for both low-LET and high-LET radiation.

Low-LET and high-LET radiation are associated with radionuclides released to the environment during operation of the WIPP and during operation of other related facilities. An evaluation of the decay modes of the specific radionuclides released from these facilities has been made to determine the type of radiation most applicable for specific health-effect calculations performed for this SEIS.

Health effects estimators for low-LET and high-LET radiation were derived for use in estimating health effects based on an evaluation of the data presented in the BEIR III report. The resulting health effects estimators used in this SEIS are summarized in Table A-16 of the SIS FEIS (DOE, 1986). They total 120 cancer fatalities per million person-rem for low-LET radiation and 280 cancer fatalities per million person-rem for high-LET radiation. The health effects estimator for genetic effects used in this SEIS is 257 genetic effects per million person-rem of radiation, received by the gonads, for either type of radiation.

These health effects estimators are the best estimates of risk based on present data. The estimators could vary widely, depending on the models used. For cancer fatalities estimators could range from near 0 to as high as 400 per million person-rem. For genetic effects, the risk estimators could range from 60 to 1,100 per million person-rem (DOE, 1986).

Whether the absolute-risk model or the relative-risk model is used to project radiation induced risks, the very low radiation exposures predicted in the SEIS lead to an insignificant number of health effects and risk values to the population. The use of ranges for risk estimates is not believed to be warranted in this SEIS because of the low levels of predicted risk.

The risk estimates presented in this subsection provide insight into the radiological impact that the WIPP could potentially have on the public. In response to such estimates, the government has established goals that broadly define an acceptable level of radiological and non-radiological risk (BEIR, 1980; EPA, 1986; NRC, 1986). At the present, the DOE is finalizing similar acceptable safety criteria (DOE, 1989). These acceptable risk levels provide that nuclear risks should not significantly add to other societal risks. A range of quantitative risk values (from an increase in risk of one in 100,000 to 1,000,000) have been adopted by the regulatory agencies to assure this level of safety. These values represent a risk of a health effect from nuclear facility operations that should not exceed a one-tenth of one percent (0.1 percent) to a one percent increase in the number of similar health effects resulting from all other causes.

Radiological exposure can affect terrestrial and aquatic ecosystems. The major concern ecologically is protecting the vitality and integrity of plant and animal populations. Standards for humans, however, limit an individual's risk of any serious health effect (cancer), and the total health and genetic effects on human populations. In general, ecosystem species, particularly plants, can tolerate higher exposures than those that have been determined acceptable for humans. It is highly likely that radiation levels that conform to limits designed to protect human individuals and populations will not have significant ecological effects.

Risks of Transportation-Related Radiation Exposures. Radiological risks from routine transportation are related to direct external gamma radiation. Releases are not expected during routine transportation because of the TRUPACT-II design and performance criteria. Consequently, only the risks resulting from exposure to external radiation penetrating through the shipping container are considered for the routine transportation case. Predicted health impacts associated with routine transportation are presented in Table 5.9. Estimated maximum exposures associated with normal operations project up to 2.6×10^{-2} and 1.2×10^{-3} excess latent cancer fatalities (LCFs) in the transportation work-force per year during the Disposal Phase from truck and rail transportation, respectively, and 7.8×10^{-3} LCFs per year for truck transport during the Test Phase. Radiation exposures to the public from combined normal operations and accidents provide estimates of 1.9×10^{-2} and 1.3×10^{-2} excess LCFs per year in the total population along WIPP transportation corridors for the 100 percent truck and the maximum rail transport cases, respectively, for the Disposal Phase of the Proposed Action and 4.2×10^{-3} LCFs per year for the Test Phase of the Proposed Action. The cumulative risk to the entire population along the transportation corridors associated with transportation accidents is very small. Also, the maximum risk of developing a fatal cancer by the hypothetical individual exposed to all shipments to the WIPP is 0.76 and 0.59 chances per million for the 100 percent truck and maximum rail scenarios, respectively. The radiological exposure to the ecosystems along the route would also be extremely small, and the associated impacts resulting from that exposure would be undetectable. To put the concept of "lifetime excess cancer risk" in perspective, the "background level" of cancer occurrence in the general population is about one in four, or 225,000 cases in a population of 1,000,000 (American Cancer Society, 1988).

No early fatalities or early morbidities would result from these exposures. Based on a rate of 2.8 latent cancer fatality per 10,000 person-rem exposure, 3.5×10^{-1} excess latent cancer fatalities would be expected in the population exposed to the "bounding case" transportation accident.

5 5-28 Table 5.9 In Public, Proposed Action, Disposal Phase column:

(1) Fourth number from top, 7.6 x 10^{-7}, should read 7.3 x 10^{-7}.

(2) Fifth number from top, 1.1 x 10^{-2}, should read 1.2 x 10^{-2}.

(3) Sixth number from top, 2.3 x 10^{-3}, should read 1.3 x 10^{-3}.

(4) Last number in column, 5.9 x 10^{-7}, should read 7.6 x 10^{-7}.

transportation to the WIPP

				Public		
				Action		
				hase	Disposal Phase	Alternative Action
100% Truck Normal	7.8×10^{-3}	2.6×10^{-2}	2.8×10^{-2}	3.4×10^{-3}	1.6×10^{-2}	1.7×10^{-2}
Accident	- - -	- - -	- - -	8.1×10^{-4}	2.7×10^{-3}	2.8×10^{-3}
TOTAL	7.8×10^{-3}	2.6×10^{-2}	2.8×10^{-2}	4.2×10^{-3}	1.9×10^{-2}	2.0×10^{-2}
Hypothetical Maximum Exposed Individual [d]					7.6×10^{-7}	7.3×10^{-7}
Maximum Rail Normal	- - -	1.2×10^{-3}	1.3×10^{-3}	- - -	1.1×10^{-2}	1.3×10^{-2}
Accident	- - -	- - -	- - -		2.3×10^{-3}	1.4×10^{-3}
					1.3×10^{-2}	1.4×10^{-2}
					5.9×10^{-7}	7.3×10^{-7}

5 5-28 Table 5.9 In Public, Alternative Action column: last number in column, 7.3 x 10^{-7}, should read 7.6 x 10^{-7}.

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[a] Transportation health risks are expressed as the annual number of excess fatal cancers estimated in the entire population along the shipping routes. (Both CH and RH TRU waste shipments are included.) Risks are expressed in exponential form; i.e., 1.0×10^{-3} is equivalent to 1.0 chance of a cancer in 1,000 for each year of operation.

[b] Risk of contracting fatal cancer: 2.8×10^{-4} fatalities/person-rem.

[c] Annual health effects risk estimates for genetic effects would be somewhat less (a factor of 0.918) than the risks presented in the table for cancer fatality risks.

[d] Risk expressed as that individual's chances of contracting a fatal cancer due to the transportation of wastes to the WIPP. (Assumed to be living 30 meters from transportation routes at the WIPP boundary.)

5.2.2.2 Hazardous Chemical Risk Assessment for Transportation. This section evaluates risks associated with exposures to hazardous chemicals during the transport of TRU waste to the WIPP. Potential hazard chemical exposures to a person receiving a maximum concentration of a chemical during an accident are discussed. Accidents involving hazardous chemicals are evaluated as short-term events with respect to potential exposures and associated risks.

Routine Exposures from Transportation Activities. As described in SEIS Subsection 5.2.2.1, during routine transportation, minimal gamma exposures exist at the surface of the TRUPACT-IIs. Such an exposure mechanism is not feasible with regard to the hazardous chemical components of the waste, as they are completely contained within the TRUPACT-II package. Thus, no exposures or risks to human health are posed by the hazardous chemical components under routine transportation conditions.

This assessment examines the potential human health impacts resulting only from "bounding case" accident scenarios that are postulated for truck and rail shipments of TRU mixed waste to the WIPP.

Transportation Accidents. The "bounding case" accident scenario was based on the unlikely assumption that all TRUPACT-IIs and all 14 drums in every TRUPACT-II included in a waste shipment are breached. Consistent with the radiological assessment, the entire releasable fraction of each chemical considered was used to evaluate potential risks (this fraction for the chemical component consists of vapors and suspended particulates). Whenever possible, assumptions used in the radiological assessment (SEIS Subsection 5.2.2.1) provide the basis for assessing the risks of accidents posed by the hazardous chemical component of the wastes. Any differences in assumptions noted in this section are necessary to account for the actual forms in which the chemicals are available for release during an accident. For example, while the radioactive component of the waste may be released only as particulates, the organic chemicals available for release exist primarily as vapors; thus, specific assumptions that addressed the behavior of vapors have been developed. These assumptions are described in more detail below.

Selection of Hazardous Chemicals for Assessment. The hazardous chemicals examined in this assessment are carbon tetrachloride; methylene chloride; 1,1,1,-trichloroethane; 1,1, 2-trichloro-1,2,2-trifluoroethane (Freon-113); trichloroethylene; and lead.

As wastes, these chemicals are considered hazardous by the EPA (40 CFR Part 261, Subparts C and D) and are the only EPA-regulated hazardous constituents that may potentially comprise greater than one percent by weight of the wastes transported to the WIPP (Rockwell, 1988). All others are estimated to comprise less than one percent each by weight, and most exist only in trace quantities (WEC, 1989). Although trichloroethylene was not reported in newly-generated waste from the Rocky Flats Plant, it was detected in the headspace gas of drums containing older wastes at the Idaho National Engineering Laboratory. Because data on the gas phase concentration of trichloroethylene were available, it was included in this assessment. The volatile organic compounds listed above have not been identified in RH TRU waste; lead, however, is found in RH and CH TRU wastes.

TABLE 5.9 Human health risks associated with radiological exposures during Proposed Action transportation to the WIPP

	Maximum Annual Health Risk[a,b,c] (latent cancer fatalities/year)					
	Occupational			Public		
	Proposed Action			Proposed Action		
Transportation Activity	Test Phase	Disposal Phase	Alternative Action	Test Phase	Disposal Phase	Alternative Action
100% Truck Normal	7.8×10^{-3}	2.6×10^{-2}	2.8×10^{-2}	3.4×10^{-3}	1.6×10^{-2}	1.7×10^{-2}
Accident	- - -	- - -	- - -	8.1×10^{-4}	2.7×10^{-3}	2.8×10^{-3}
TOTAL	7.8×10^{-3}	2.6×10^{-2}	2.8×10^{-2}	4.2×10^{-3}	1.9×10^{-2}	2.0×10^{-2}
Hypothetical Maximum Exposed Individual[d]					7.6×10^{-7}	7.3×10^{-7}
Maximum Rail Normal	- - -	1.2×10^{-3}	1.3×10^{-3}	- - -	1.1×10^{-2}	1.3×10^{-2}
Accident	- - -	- - -	- - -	- - -	2.3×10^{-3}	1.4×10^{-3}
TOTAL	- - -	1.2×10^{-3}	1.3×10^{-3}	- - -	1.3×10^{-2}	1.4×10^{-2}
Hypothetical Maximum Exposed Individual[d]				- - -	5.9×10^{-7}	7.3×10^{-7}

[a] Transportation health risks are expressed as the annual number of excess fatal cancers estimated in the entire population along the shipping routes. (Both CH and RH TRU waste shipments are included.) Risks are expressed in exponential form; i.e., 1.0×10^{-3} is equivalent to 1.0 chance of a cancer in 1,000 for each year of operation.

[b] Risk of contracting fatal cancer: 2.8×10^{-4} fatalities/person-rem.

[c] Annual health effects risk estimates for genetic effects would be somewhat less (a factor of 0.918) than the risks presented in the table for cancer fatality risks.

[d] Risk expressed as that individual's chances of contracting a fatal cancer due to the transportation of wastes to the WIPP. (Assumed to be living 30 meters from transportation routes at the WIPP boundary.)

5.2.2.2 Hazardous Chemical Risk Assessment for Transportation. This section evaluates risks associated with exposures to hazardous chemicals during the transport of TRU waste to the WIPP. Potential hazard chemical exposures to a person receiving a maximum concentration of a chemical during an accident are discussed. Accidents involving hazardous chemicals are evaluated as short-term events with respect to potential exposures and associated risks.

Routine Exposures from Transportation Activities. As described in SEIS Subsection 5.2.2.1, during routine transportation, minimal gamma exposures exist at the surface of the TRUPACT-IIs. Such an exposure mechanism is not feasible with regard to the hazardous chemical components of the waste, as they are completely contained within the TRUPACT-II package. Thus, no exposures or risks to human health are posed by the hazardous chemical components under routine transportation conditions.

This assessment examines the potential human health impacts resulting only from "bounding case" accident scenarios that are postulated for truck and rail shipments of TRU mixed waste to the WIPP.

Transportation Accidents. The "bounding case" accident scenario was based on the unlikely assumption that all TRUPACT-IIs and all 14 drums in every TRUPACT-II included in a waste shipment are breached. Consistent with the radiological assessment, the entire releasable fraction of each chemical considered was used to evaluate potential risks (this fraction for the chemical component consists of vapors and suspended particulates). Whenever possible, assumptions used in the radiological assessment (SEIS Subsection 5.2.2.1) provide the basis for assessing the risks of accidents posed by the hazardous chemical component of the wastes. Any differences in assumptions noted in this section are necessary to account for the actual forms in which the chemicals are available for release during an accident. For example, while the radioactive component of the waste may be released only as particulates, the organic chemicals available for release exist primarily as vapors; thus, specific assumptions that addressed the behavior of vapors have been developed. These assumptions are described in more detail below.

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As wastes, these chemicals are considered hazardous by the EPA (40 CFR Part 261, Subparts C and D) and are the only EPA-regulated hazardous constituents that may potentially comprise greater than one percent by weight of the wastes transported to the WIPP (Rockwell, 1988). All others are estimated to comprise less than one percent each by weight, and most exist only in trace quantities (WEC, 1989). Although trichloroethylene was not reported in newly-generated waste from the Rocky Flats Plant, it was detected in the headspace gas of drums containing older wastes at the Idaho National Engineering Laboratory. Because data on the gas phase concentration of trichloroethylene were available, it was included in this assessment. The volatile organic compounds listed above have not been identified in RH TRU waste; lead, however, is found in RH and CH TRU wastes.

With regard to toxicity characteristics, carbon tetrachloride, trichloroethylene and methylene chloride are considered potential carcinogens by the EPA, and 1,1,1-trichloroethane and Freon-113 may produce adverse somatic effects. Lead is the most abundant metal found in the waste, by weight and volume (WEC, 1989). The risks associated with exposure to the relatively high concentrations of lead released during an accident are expected to bound the risks associated with exposure to any of the other metals, existing, as they do, in much smaller quantities (WEC, 1989). In sufficient concentrations, exposure to lead has been found to cause damage to the central nervous system and loss of kidney function. Further discussion describing how hazardous chemical constituents were selected and evaluated is provided in SEIS Subsection 5.2.4. Detailed toxicity information for each constituent is provided in SEIS Appendix G.

Quantities of Hazardous Chemicals Released. The following assumptions provided the basis for determining the total fraction of volatile organic compounds available for release during a transportation accident:

- An average void volume of 147.26 liters per drum was assumed (based on data collected by Clements and Kudera, 1985).
- The concentrations of volatile organic compounds in the void volume of each drum were derived from headspace gas measurements reported by Clements and Kudera (1985), which were based on analyses of TRU mixed wastes stored in containers at the Idaho National Engineering Laboratory (SEIS Subsection 5.2.3). The following average drum headspace concentration (in grams per cubic meter) was calculated for each volatile organic compound evaluated in this assessment: carbon tetrachloride, 1.9; methylene chloride, 0.5; 1,1,1-trichloroethane, 13.2; Freon-113, 1.2; and trichloroethylene, 0.7.
- One hundred percent of the total quantity (in grams) of each volatile organic compound within the void volume of each drum was discharged within the TRUPACT-II cavity prior to release to the atmosphere during an accident.

The assumptions used to determine the fraction of lead that may be released during an accident are as follows:

- The total quantity of lead released was comprised of particulates resuspended in the atmosphere of the drum and additional lead that was released under conditions in which extremely high temperatures cause a portion of the lead to vaporize.
- Each drum contains 227 kg of waste. A weighted average concentration for lead in sludges generated by the Rocky Flats Plant (Rockwell, 1988) was calculated and used to determine the quantity of lead potentially present in particulate form. The average weighted concentration of lead in these wastes was calculated to be 10 mg/kg.

- Of the total material contained within each TRUPACT-II, 0.02 percent may be resuspended and released to the environment as particulates (SEIS Appendix D); for this analysis, lead comprised this entire particulate fraction. All of these particulates were assumed to be less than 10 microns in diameter, all of which is respirable.

- In addition to the particulate lead, during a fire the surface area over which vaporization of lead occurs was calculated as the product of the number of drums and the cross-sectional area of a drum. (For RH TRU transportation, the outside surface area of a canister was included in the total area.)

- Temperature inside the TRUPACT-II during the fire was assumed to be 1,000 degrees Fahrenheit (811 degrees Kelvin); the fire's duration was 2.0 hours. The temperature inside the TRUPACT-II was assumed to reach 1,000 degrees Fahrenheit and was maintained for 1.5 hours.

In considering releases of lead and volatile organic compounds, it was assumed that, for CH TRU wastes, three TRUPACT-IIs each contained 14 drums of waste during truck shipments, and that there would be six TRUPACT-IIs on each railcar shipment. For RH TRU waste, each truck would carry one cask, and each railcar would carry two casks.

It was also assumed that the maximally exposed member of the public in the release scenarios would be located 100 feet (30 meters) away from the point of release and in the pathway of the contaminant plume. This distance was the point of maximum concentration predicted by the PUFF model (Petersen, 1982).

General Method for Estimating Human Health Risks. The concentration of a hazardous chemical in the atmosphere following an accident would be less than the concentration existing within a TRUPACT-II package prior to release. It can be assumed that, following a release, dispersion in the atmosphere will result in diminishing concentrations over time and distance. Thus, if the concentration of any constituent within the TRUPACT-II is below a health-based limit prior to release, when it is most concentrated, then no further modeling is considered to be required. If the initial concentration of a constituent is greater than the health-based limit, additional modeling is required to determine the concentration to which a receptor would be exposed during a release.

Human Health Consequences of Chemical Releases During Transport. The concentration of hazardous chemicals received by a maximally exposed individual was determined using the PUFF model (Petersen, 1982). The potential receptor was assumed to be an average individual weighing 70 kg whose daily respiratory volume was 20 m^3/day (EPA, 1985). The receptor was located 164 feet (50 meters) away from the accident in the pathway of the contaminant plume.

The volatile organic compounds released as gases during an accident in which drums and TRUPACT-IIs were breached were assumed to be available for intake by a receptor. The total concentrations of volatile organics released during truck and railcar accidents are shown in Table 5.10. As can be seen, the total concentration of each organic constituent (except carbon tetrachloride, which is approximately equal to the time-weighted average threshold limit value (TWA-TLV) within a TRUPACT-II prior to a failure of the packaging is well below the TWA-TLV. TWA-TLVs are intended to protect workers' health over a career of exposure, 8 hours per work day. These low concentrations suggest that no significant health detriments would result from exposure to volatilized organic compounds at their most concentrated state, that is, within the TRUPACT-II prior to a breach of the package. Any subsequent dilution resulting from dispersion through the atmosphere would result in concentrations at the receptor location that are even further below the TWA-TLV level.

To determine whether an accident involving a fire would release a greater concentration of volatile organics, the effects of temperature increases were examined with regard to the generation of gases within a TRUPACT-II. The volatile organic compounds present in the waste include compounds that exert appreciable vapor pressures at room temperatures (e.g., Freon-113 and methylene chloride). Based on the data reported by Clements and Kudera (1985), the concentrations of volatile organic compounds in the headspace of the drums are well below the saturation values for these compounds in their pure state. It should be noted that headspace gas concentrations cannot be directly correlated to the total concentrations in the waste because of the complex nature of the vapor-waste equilibria distribution of the organics. For example, in waste forms with bound water (i.e., solidified sludges), the vapor pressure of the organics is reduced appreciably. Clements and Kudera (1985) observed a decrease in the concentrations of volatile organics in the headspace of drums containing combustibles when they were vented for 13 weeks and then purged, sealed, and reequilibrated for 13 more weeks indicating the source term of the organics was limited. In addition, at the temperature postulated for the bounding case accident (i.e., 1300° K), it is highly likely that the volatile organics would be consumed in the fire. Because of the lack of analytical data on the total concentrations of volatile organics in TRU waste, a quantitative estimation of risk associated with organics released from a fire was not possible. Based on the available information, the contribution to risk associated with the releases of volatile organic compounds involved in a fire was considered limited.

With regard to lead, it is similarly assumed that the receptor is exposed to the entire amount released, which, during a fire scenario, is the sum of the vapor and particulate phases. Consistent with the radiological analyses, an average weight of 227 kg per drum was used to calculate the particulate release fraction. Based on the 10 mg/kg of lead per drum, the total quantity of lead was 2.3 g per drum. To estimate the human health risk associated with exposure to this lead, a hazard index was calculated as described in SEIS Appendix G. The rate of particulate lead deposition in the lungs may range from approximately 30 to 50 percent of the particles inhaled, while up to 70 percent of deposited lead may be absorbed during a 30-minute exposure period (ATSDR, 1988). The concentrations of lead received by an individual receiving the maximum exposure downwind from truck and rail car shipments of CH and RH TRU waste are given in Table 5.11. Estimates of intake per exposure were compared with TWA-TLVs (ACGIH, 1986). The hazard index for a given chemical is defined as the ratio between the estimated intake of that chemical and a reference level. A hazard index of less than one implies that the exposure to the chemical is below the reference level. The TLV-based hazard indices for truck and rail car shipments involving CH TRU waste were 1.0×10^{-3} and 2.1×10^{-3}, respectively. These values are approximately three orders of magnitude below unity. Releases of lead from RH TRU waste shipments involved in this

5	5-33	Table 5.10	Table title, "Concentrations of volatile organic compounds available for release during accident scenarios" should be followed by a superscript [a] to correspond with footnote [a].

CHEMICAL	TWA-TLV[b] (g/m^3)	Truck shipment Three TRUPACT-IIs (g/m^3)	Rail shipment Six TRUPACT-IIs (g/m^3)
Methylene Chloride	$1.8x10^{-1}$	$4.4x10^{-3}$	$8.8x10^{-3}$
Freon 113	7.6	$1.1x10^{-2}$	$2.2x10^{-2}$
1,1,1-Trichloroethane	1.9	$1.2x10^{-1}$	$2.4x10^{-1}$
Carbon Tetrachloride	$3.0x10^{-2}$	$1.7x10^{-2}$	$3.4x10^{-2}$
Trichloroethylene	$2.7x10^{-1}$	$6.5x10^{-3}$	$1.3x10^{-2}$

[a] Initial concentrations of volatile organic compounds estimated from data obtained from Clements and Kudera (1985).

[b] Time-weighted average Threshold Limit Values (TWA-TLVs) are occupational exposure limits for an eight-hour work day throughout a career of exposure (ACGIH, 1986). Transportation accidents are short-term events estimated for a 30-minute maximum exposure to an individual.

accident scenario resulted in hazard indices approximately four orders of magnitude below unity. The intakes of lead over a 30-minute exposure period from an accident involving shipments of either CH or RH TRU waste are well below the reference level.

In an accident involving a severe fire, there is a potential for release of a wide range of combustion products from the burning of plastics and other combustibles. As discussed in Subsection 5.2.2.1, a major breach of the TRUPACT-II was not considered as a reasonable event, and therefore external oxygen/air sources would be limiting (i.e., when internal combustion is limited).

of the pack
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TRUPACT-II p package. Any subsequent dilution resulting from
dispersion through the atmosphere would result in concentrations at the receptor location that are even further below the TWA-TLV level.

To determine whether an accident involving a fire would release a greater concentration of volatile organics, the effects of temperature increases were examined with regard to the generation of gases within a TRUPACT-II. The volatile organic compounds present in the waste include compounds that exert appreciable vapor pressures at room temperatures (e.g., Freon-113 and methylene chloride). Based on the data reported by Clements and Kudera (1985), the concentrations of volatile organic compounds in the headspace of the drums are well below the saturation values for these compounds in their pure state. It should be noted that headspace gas concentrations cannot be directly correlated to the total concentrations in the waste because of the complex nature of the vapor-waste equilibria distribution of the organics. For example, in waste forms with bound water (i.e., solidified sludges), the vapor pressure of the organics is reduced appreciably. Clements and Kudera (1985) observed a decrease in the concentrations of volatile organics in the headspace of drums containing combustibles when they were vented for 13 weeks and then purged, sealed, and reequilibrated for 13 more weeks indicating the source term of the organics was limited. In addition, at the temperature postulated for the bounding case accident (i.e., 1300° K), it is highly likely that the volatile organics would be consumed in the fire. Because of the lack of analytical data on the total concentrations of volatile organics in TRU waste, a quantitative estimation of risk associated with organics released from a fire was not possible. Based on the available information, the contribution to risk associated with the releases of volatile organic compounds involved in a fire was considered limited.

With regard to lead, it is similarly assumed that the receptor is exposed to the entire amount released, which, during a fire scenario, is the sum of the vapor and particulate phases. Consistent with the radiological analyses, an average weight of 227 kg per drum was used to calculate the particulate release fraction. Based on the 10 mg/kg of lead per drum, the total quantity of lead was 2.3 g per drum. To estimate the human health risk associated with exposure to this lead, a hazard index was calculated as described in SEIS Appendix G. The rate of particulate lead deposition in the lungs may range from approximately 30 to 50 percent of the particles inhaled, while up to 70 percent of deposited lead may be absorbed during a 30-minute exposure period (ATSDR, 1988). The concentrations of lead received by an individual receiving the maximum exposure downwind from truck and rail car shipments of CH and RH TRU waste are given in Table 5.11. Estimates of intake per exposure were compared with TWA-TLVs (ACGIH, 1986). The hazard index for a given chemical is defined as the ratio between the estimated intake of that chemical and a reference level. A hazard index of less than one implies that the exposure to the chemical is below the reference level. The TLV-based hazard indices for truck and rail car shipments involving CH TRU waste were 1.0×10^{-3} and 2.1×10^{-3}, respectively. These values are approximately three orders of magnitude below unity. Releases of lead from RH TRU waste shipments involved in this

TABLE 5.10 Concentrations of volatile organic compounds available for release during accident scenarios

CHEMICAL	TWA-TLV[b] (g/m^3)	Truck shipment	Rail shipment
		Three TRUPACT-IIs (g/m^3)	Six TRUPACT-IIs (g/m^3)
Methylene Chloride	1.8×10^{-1}	4.4×10^{-3}	8.8×10^{-3}
Freon 113	7.6	1.1×10^{-2}	2.2×10^{-2}
1,1,1-Trichloroethane	1.9	1.2×10^{-1}	2.4×10^{-1}
Carbon Tetrachloride	3.0×10^{-2}	1.7×10^{-2}	3.4×10^{-2}
Trichloroethylene	2.7×10^{-1}	6.5×10^{-3}	1.3×10^{-2}

[a] Initial concentrations of volatile organic compounds estimated from data obtained from Clements and Kudera (1985).

[b] Time-weighted average Threshold Limit Values (TWA-TLVs) are occupational exposure limits for an eight-hour work day throughout a career of exposure (ACGIH, 1986). Transportation accidents are short-term events estimated for a 30-minute maximum exposure to an individual.

accident scenario resulted in hazard indices approximately four orders of magnitude below unity. The intakes of lead over a 30-minute exposure period from an accident involving shipments of either CH or RH TRU waste are well below the reference level.

In an accident involving a severe fire, there is a potential for release of a wide range of combustion products from the burning of plastics and other combustibles. As discussed in Subsection 5.2.2.1, a major breach of the TRUPACT-II was not considered as a reasonable event, and therefore external oxygen/air sources would be limiting (i.e., when internal combustion is limited).

TABLE 5.11 Exposures and risk associated with releases of lead during an upper-bound accident scenario

Mode of transport	Quantity of lead available for release (mg)	Maximum receptor concentration (mg/m^3)	TLV-based estimated intake[a] (mg/exposure)	TLV-based hazard index[b]
		CH TRU Waste		
Truck	22.3	4.5×10^{-3}	1.9×10^{-3}	1.0×10^{-3}
Rail	44.5	8.9×10^{-3}	3.7×10^{-3}	2.1×10^{-3}
		RH TRU Waste		
Truck	3.2	6.5×10^{-4}	2.7×10^{-4}	1.5×10^{-4}
Rail	6.5	1.3×10^{-3}	5.4×10^{-4}	3.0×10^{-4}

[a] Estimated intakes are calculated by multiplying three quantities: the concentration received by the exposed person, in milligrams per cubic meter of air; the quantity of air inhaled, in cubic meters; and the exposure period. The TLV is a time-weighted average for an 8-hour work day intended to protect workers over a career of exposure. Therefore, the TLV-based estimated intake using the formula given above with an exposure period of 30 min provides a very conservative reference level.

[b] TLV-based hazard index is the estimated intake divided by the TLV-based allowable intake.

In conclusion, no adverse human health effects are expected to result from the exposure to the hazardous chemical constituents of TRU waste released during a transportation accident in which all TRUPACT-IIs in a shipment are breached, and any human health risks associated with such releases are negligible. The two primary reasons for the lack of adverse impacts are the low initial concentrations of chemicals within the waste containers, and the physical form of the waste which limits the concentrations available for release.

5.2.2.3 Physical injuries/fatalities during accidents and risks related to vehicle emissions. This subsection discusses the risks of physical injuries and deaths during transportation accidents and the risks associated with vehicle emissions during incident-free transportation. None of these risks is related to radioactivity or hazardous chemicals and would be the same as the risk resulting in everyday life from transporting nonradioactive materials. The accident risks are calculated as numbers of injuries and deaths; the vehicle-emission risks are calculated as numbers of excess latent cancer fatalities in the exposed population.

These risks are calculated on a per-shipment basis and on a lifetime basis by alternative. Estimates of the per-shipment risk include the probability of latent cancer fatalities from vehicle-emission pollutants and accident-related injuries and deaths of a single round trip. Cumulative risk estimates were determined by multiplying per-shipment risks by total shipments for the five-year Test Phase and for the 20-year Disposal Phase, depending on the alternative and the transportation mode.

The average distance and population zone fractions are provided in SEIS Appendix D, Table D.4.2. These data are used with Tables 5.12 and 5.13 to calculate the per-shipment risk for truck and rail alternatives. The estimates in Table 5.12 represent the estimated additional urban-area health effects from the particulates and sulfur dioxide emitted by truck or locomotive diesel engines during a shipment. Table 5.14 presents the estimated per-shipment risk for truck and rail transport. The estimated risk shown for each generating and storage facility is on a round-trip basis. Section D.4 in SEIS Appendix D presents detailed descriptions of the methods, models, assumptions, and results used to estimate risks.

The transportation analysis presented in this SEIS is based on the best truck-accident datum, $1.1x10^{-6}$ accident per kilometer (NRC, 1977) available at this time. In judging the validity of using this data in the present analysis, it is necessary to consider the rates of TRU waste shipments and total transport rates, the relative magnitude of present accident rates, and the relative magnitude of national and route-specific accident rates. Recent national estimates of truck accident rates are not available. The validity of the earlier estimates may, however, be judged in comparison with recent data for specific States. Such data are available for 1986 and 1987 and are presented in SEIS Appendix D, Section D.4. The accident rates used in this SEIS are comparable to these recent data. The validity of the historical national data to the specific routes considered in this SEIS can also be evaluated by comparing with the state data referenced above. Again, the accident rates are comparable, and the SEIS analysis is therefore considered applicable to the routes analyzed.

Results. Table 5.14 presents the per-shipment risk for truck and rail for shipping TRU wastes to the WIPP. For the shipment of TRU waste, the total risks for the Test Phase are 0.014 latent cancer fatality, (LCF), 0.61 fatality, and 7.8 injuries for truck shipment. For CH TRU waste transport by truck, the total estimated risk for all sites for the 20-year Disposal Phase are 0.12 LCF, 5.6 fatalities, and 71 injuries. For transport by rail, the total estimated risks for the Test Phase and the Disposal Phase are 0.09 LCF, 2.4 fatalities, and 27 injuries.

For RH TRU waste being transported by truck, the estimated risks for LCFs, fatalities, and injuries are 0.027, 2.1, and 27, respectively. The estimated risks for rail transportation are 0.034 LCF, 0.62 fatality, and 6.5 injuries. SEIS Appendix D (Tables D.4.10 and D.4.11) presents the total-risk estimates for truck and rail for each alternative.

TABLE 5.12 Estimated risks from vehicle-emission pollutants[a,b]

Mode	Risk (latent cancer fatalities per kilometer)
Rail	1.3×10^{-7}
Truck	1.0×10^{-7}

[a] The risks are estimated only for travel through urban areas. The pollutants considered are particulates and sulfur dioxide.

[b] Data from Rao et al. (1982).

TABLE 5.13 Nonradiological and nonchemical unit risk factors [a]

		Risk per kilometer		
Mode	Zone	LCF[a]	Injuries[b]	Fatalities[b]
Truck	Rural	0	8.28×10^{-7}	6.80×10^{-8}
	Suburban	0	3.83×10^{-7}	1.67×10^{-8}
	Urban	1.0×10^{-7}	3.83×10^{-7}	9.60×10^{-8}
Rail	Rural	0	2.97×10^{-7}	2.82×10^{-8}
	Suburban	0	2.97×10^{-7}	2.82×10^{-8}
	Urban	1.3×10^{-7}	2.97×10^{-7}	2.82×10^{-7}

LCF - Latent cancer fatalities

[a] From Rao et al. (1982).

[b] Cashwell et al. (1986), Appendix 4, Tables 4-4A and 4-4B. Nonradiological unit risk factors determined from US Department of Transportation, Research and Special Programs Administration, Transportation Systems Center, 1986, National Transportation Statistics, Annual Report, 1986, Report No. DOT-TSC-RSPA-86-3, "Truck Profile, Heavy Trucks Category", and "Rail Profile, Class I Railroads Category," for 1983 and 1984 calendar years.

TABLE 5.14 Per shipment nonradiological risk of waste shipments[a,b,c]

Shipment Origin Site	Zone	Truck			Rail		
		Normal Transportation LCF(c)	Accident Case		Normal Transportation LCF(c)	Accident Case	
			Fatalities	Injuries		Fatalities	Injuries
ANLE	Rural	0.00E+00	2.37E-04	2.89E-03	0.00E+00	1.09E-04	1.15E-03
	Suburban	0.00E+00	8.12E-06	3.73E-04	0.00E+00	2.27E-05	2.39E-04
	Urban	4.46E-07	4.28E-08	1.71E-06	8.60E-06	1.87E-06	1.97E-05
HANF	Rural	0.00E+00	3.59E-04	4.37E-03	0.00E+00	1.83E-04	1.93E-03
	Suburban	0.00E+00	1.38E-05	3.16E-04	0.00E+00	2.40E-05	2.52E-04
	Urban	5.54E-06	5.32E-07	2.12E-05	6.72E-06	1.46E-06	1.54E-05
INEL	Rural	0.00E+00	2.83E-04	3.44E-03	0.00E+00	1.43E-04	1.51E-03
	Suburban	0.00E+00	1.13E-05	2.59E-04	0.00E+00	1.57E-05	1.65E-04
	Urban	5.87E-06	5.64E-07	2.25E-05	5.16E-06	1.12E-06	1.18E-05
LANL	Rural	(d)	6.76E-05	8.24E-04	(e)	(e)	(e)
	Suburban		1.83E-06	4.19E-05			
	Urban		0.00E+00	0.00E+00			
LLNL	Rural	0.00E+00	2.75E-04	3.35E-03	0.00E+00	1.44E-04	1.52E-03
	Suburban	0.00E+00	7.91E-06	1.82E-04	0.00E+00	2.43E-05	2.56E-04
	Urban	1.74E-05	1.67E-06	6.65E-05	5.49E-06	1.19E-06	1.25E-05
MOUND	Rural	0.00E+00	2.43E-04	2.96E-03	0.00E+00	1.17E-04	1.23E-03
	Suburban	0.00E+00	1.91E-05	4.37E-04	0.00E+00	3.24E-05	3.41E-04
	Urban	2.37E-06	2.27E-07	4.53E-06	1.33E-05	2.89E-06	3.05E-05
NTS	Rural	0.00E+00	2.44E-04	2.97E-03	(e)	(e)	(e)
	Suburban	0.00E+00	7.74E-06	1.78E-04			
	Urban	8.28E-07	7.94E-08	3.17E-06			
ORNL	Rural	0.00E+00	2.32E-04	2.83E-03	0.00E+00	1.18E-04	1.24E-03
	Suburban	0.00E+00	1.50E-05	3.44E-04	0.00E+00	2.80E-05	2.94E-04
	Urban	3.04E-06	2.92E-07	1.16E-05	8.87E-06	1.92E-06	2.03E-05
RFP	Rural	0.00E+00	1.57E-04	1.92E-03	0.00E+00	8.64E-05	9.09E-04
	Suburban	0.00E+00	7.38E-06	1.69E-04	0.00E+00	1.16E-05	1.22E-04
	Urban	5.63E-06	5.40E-07	2.16E-05	7.81E-06	1.69E-06	1.78E-05
SRP	Rural	0.00E+00	2.58E-04	3.14E-03	0.00E+00	1.32E-04	1.39E-03
	Suburban	0.00E+00	2.14E-05	4.90E-04	0.00E+00	3.89E-05	4.10E-04
	Urban	3.06E-06	2.94E-07	1.17E-05	1.28E-05	2.78E-06	2.93E-05
TOTAL		4.41E-05	2.47E-03	3.16E-02	6.88E-05	1.25E-03	1.31E-02

NOTES:

[a] Calculated risks include the impact of the return trip from WIPP to the generator/storage facility.

[b] The nonradiological risk per shipment is calculated using the travel information, the incident-free (pollution) consequence factors, and the accident risk factors presented in the SEIS Appendix D.

[c] LCFs represent latent cancer fatalities resulting from incremental vehicle pollution in urban areas.

[d] The truck route from LANL to the WIPP passes through no large urban areas.

[e] The rail mode is not available for this site.

5.2.3 Risk assessment and analysis of radiological environmental consequences of operations and possible retrieval at the WIPP

This subsection establishes the general approach used in the SEIS to analyze both radiological and nonradiological impacts and examines the potential radiological environmental consequences associated with emplacement and, if necessary, retrieval of wastes from the WIPP. This subsection discusses potential releases and release pathways and presents the resulting exposure to humans or levels of environmental contamination with the resulting radiological impacts to human health and safety, and to the environment. Both routine operations and potential accident scenarios are considered. Subsection 5.2.3.1 describes the general methodology used to assess the potential risks posed by the radiological and the hazardous chemical waste constituents.

5.2.3.1 General Risk Assessment Methodology. Environmental consequences of possible releases of radionuclides and hazardous chemicals proposed for emplacement in the WIPP are analyzed through a process of risk assessment. Risk assessment is a method of determining the likelihood and extent of consequences to human health and the environment posed by certain activities or events. The focus of the risk assessment is the waste management process proposed for the WIPP which includes unloading of TRUPACT-II containers at the Waste Handling Building, placement of wastes in the repository, and retrieval of the waste at the conclusion of the test phase, if determined necessary. Some identified risks are analyzed quantitatively while others are evaluated using qualitative methods.

Overall Approach. The risk assessment in this subsection of the SEIS considers radiological and hazardous chemical risks to workers (occupational risks), risks to the general public, and impacts to the environment (ecological risks to ecosystems) at or near the WIPP facility. SEIS Subsection 3.1.1 and Appendix B provide information on radiological and hazardous chemical characteristics of radioactive mixed waste, respectively. Exposures (doses) potentially received by human populations or components of the ecosystem are derived from projected routine and postulated accidental releases. Human health effects are generally assessed in terms of excess lifetime fatal cancer risk. Other environmental and ecological effects are estimated in terms of adverse consequences on air or water quality and the degradation of ecological resources.

The risk assessment process can be generally divided into five basic steps:

1) Identify hazards (risks) considering the radiological, toxicological, and physical characteristics of the waste.

2) Evaluate routine operations or postulate reasonably foreseeable accident scenarios that may result in a release of radioactive material or toxic chemicals.

3) Conduct an exposure assessment by evaluating migration pathways and estimating exposure concentrations to which human and nonhuman receptors are subjected. Exposures are assessed by use of computer models such

as AIRDOS-EPA for radiological releases and the Industrial Source Complex (ISC) Code for chemical releases.

4) Determine consequences (impacts) of exposures to individual receptors according to established dose-response relationships in terms of excess risk of cancer or noncarcinogenic effects.

5) Characterize the overall risk in terms of human health consequences and potential environmental effects.

Assumptions and Considerations of Uncertainty. TRU waste inventories are discussed in SEIS Appendix B. Risk assessments assume that the maximum approved quantity of waste will be shipped to the WIPP. During the Test Phase, estimates are based on the equivalent of 110,000 drums (620,000 ft^3) of CH waste or an average of 22,000 55-gallon drum equivalents per year. (As discussed in SEIS Subsection 5.2.2 and Appendix D, drums were assumed to be only 80 percent full of waste due to compaction and settling. It was assumed that 10 percent of the projected CH waste from all facilities would be sent to the WIPP during the Test Phase. Although it is recognized this scenario is extremely unlikely, the assumption will provide an upper bound of the estimated risks). The estimate used for the subsequent 20-year Disposal Phase is the equivalent of 49,500 drums per year (5.58 million ft^3) of CH wastes and 7,953 RH canisters (250,000 ft^3) giving a total estimated volume of wastes to WIPP of 6.45 million ft^3. This volume of post-1970 TRU waste is not currently projected to be available over the next 25 years. However, SEIS analyses are based on this maximum approved capacity of the WIPP to provide an upper bound on estimates of potential impacts.

To compensate for uncertainties, the overall risk assessments are biased toward health protection. For example, an off-site residential receptor was assumed to be present to the point of maximum off-site concentration. This is highly improbable and overestimates risks.

This conservative approach compensates for possible uncertainties in the risk assessment process and does not provide a "most-likely-to-occur" scenario. Unless the conservative assumptions postulated in these scenarios are true, the risks will be overestimated. If effects associated with these conservative scenarios pose no risks to workers or residential populations, it follows that less conservative scenarios associated with decreased exposures also pose low risks.

5.2.3.2 **Radiological Risk Assessment Methodology**. This section provides an overview of the methods and assumptions used to estimate potential radiological exposures (dose estimates) during WIPP operations, including unloading, handling, underground emplacement, and assumed waste retrieval activities, considering both routine operations and reasonably foreseeable accident scenarios. An overview of the AIRDOS-EPA computer model, used to evaluate releases to air, and the assumptions used to estimate potential effects of radiological releases on human health and the environment are provided in Appendix F.

Radiological dose assessments and methodologies used in this SEIS, are based on the analyses in the WIPP draft FSAR (DOE, 1988c). Differences between dose assessment methods and assumptions used in the FEIS and this SEIS are examined. Differences between radiation doses reported in the FEIS and current estimates result from refinements in inventory characterization, modifications to the facility and waste handling operations, and changes in dose modeling methodology.

Risk assessments of WIPP operations have been periodically updated since the FEIS, primarily through FSAR amendments. As discussed below, better characterization of waste inventories, facility design refinements, development of more realistic accident and routine release scenarios, and modifications of dose assessment models have resulted in refinements of the WIPP risk estimates:

> Dose Models. The FEIS (DOE, 1980) used a modified version of the computer code AIRDOS-II to calculate doses at the WIPP from routine and accident operations. AIRDOS-EPA, a modification of AIRDOS-II, is used for current risk assessments.
>
> The FEIS calculated individual organ dose commitments to the whole body, lungs, and bone. The SEIS calculates radiation exposure in terms of committed effective dose equivalents (CEDE), the expression of dose in use today. Both the FEIS and this SEIS use a 50-year dose integration period, i.e., that dose which occurs over a 50-year period following exposure because of retention of radionuclides in the body from the ingestion or inhalation of radioactive materials. The use of effective dose equivalent (EDE) rather than organ doses provides a more conservative basis for estimating risk and regulatory compliance because the EDE incorporates dose contributions from all significant exposed organs.
>
> The FEIS used internal dose conversion models recommended by the Nuclear Regulatory Commission (NRC, 1977). Internal dose conversion factors used in current calculations are provided by Dunning (DOE, 1985) and are based on the International Commission on Radiological Protection, recommendations, and models (ICRP 1977; ICRP 1979) which were endorsed by DOE Orders 5480.11 (DOE, 1988d) and 5400.3 (DOE, 1988e).
>
> Inventory and Source-Term Changes. Since the FEIS, more accurate knowledge of waste composition and volumes at the generator facilities have been gained (See Appendix B). In particular, high-level experimental wastes from the Savannah River Plant (or any DOE facility) have been deleted from the WIPP project mission. Increased quantities of high-neutron wastes are projected from Oak Ridge National Laboratory. Current projections of numbers of shipments and waste volumes also differ from those in the FEIS because of changes to the transport container capacity and the definition of what constitutes TRU waste. However, all impacts in the SEIS have been assessed based on the current maximum design capacity of 6.45 million ft^3 of waste.
>
> Current dose assessments are based on Plutonium-239 Equivalent Activity (PE-Ci) instead of the specific radionuclide distribution utilized in the FEIS. The

PE-Ci eliminates the dependency of radiological analyses of inhalation risks on knowledge of the specific radionuclide composition of each TRU waste stream. Instead radionuclides are normalized to a common radiotoxic hazard index, that of plutonium-239. Further discussion of the PE-Ci concept is provided in Appendix F of this SEIS.

Accident Scenarios. Current accident scenarios differ from those evaluated in the FEIS (Subsection 9.5) due to facility design changes and the refinement of assumptions describing reasonably foreseeable events, "material at risk" (related to changes in projected inventories and source-terms), and release mechanisms. Accident scenarios in the FEIS assumed that HEPA filters in both the Waste Handling Building and the underground storage exhaust systems function properly and mitigate atmospheric releases by a factor of 1×10^6. The SEIS conservatively assesses the impacts associated with unfiltered accidental releases from the underground (the impacts from the underground scenarios bound those from the waste handling building.)

The FEIS postulated 22 accidents involving CH waste and 21 accidents involving RH waste. Scenarios involving a surface fire, surface container failure, underground container failure (hoist drop), and an underground fire involving waste were evaluated because they were postulated to represent the most serious accidents for their respective waste categories. The FEIS determined that the "worst-case" accident was an underground fire involving 90 drums. As discussed in Appendix F (accident description C9) engineering modifications have considerably reduced the likelihood of this accident and it is no longer considered a reasonably foreseeable event.

The SEIS postulates 11 accidents involving CH waste and six accidents involving RH waste (Appendix F). The accident determined to have the maximum consequences involves a fire in an underground drum.

Model Input Parameters. Several of the FEIS input parameters are different than those used in current assessments. Estimated flow velocities, diameters, heights, and locations for the stacks are different, and facility air change rates have changed since the FEIS. Also, demographic data for the WIPP area have been updated for the current assessments. Demographic data affects the population at risk in the model and the significance of particular pathways to man. The newer data indicate more people but fewer milk and beef cattle than were assumed in the FEIS calculations.

The FEIS calculated a routine dose commitment to a person living at the residence nearest the WIPP site and a population dose for persons residing within a 50-mile radius of the site. For accident purposes, the FEIS receptor was a member of the public assumed to reside at an existing residence near the WIPP site boundary. Conservative meteorological conditions were assumed to overestimate the likely exposure. This SEIS calculates a routine dose commitment to a hypothetical individual assumed to be living at the WIPP site boundary at the point where the maximum assumed exposure would occur and to the total population within a 50-mile radius. For the current accident analyses, doses are calculated to three theoretical individuals including an individual located within the WIPP site but beyond the secured area boundary where the dose model projects the maximum concentration (maximum individual), one living at the WIPP site boundary, and one living at the residence nearest to the WIPP (Mills Ranch - referred to as the James Ranch in the FEIS).

Migration Pathways. Potential pathways for radionuclide release from the WIPP include air, ground and surface waters, and soil. Each medium is evaluated as a migration pathway for waste-related radionuclides. It was determined in the draft FSAR that the air pathway is the only significant release and exposure pathway from the WIPP during operations. Secondary pathways include ingestion of contaminated food and water and immersion in contaminated water, all of which could result from the deposition of airborne radioactive particulates.

Air Pathway. Vapors and suspended particulates may be dispersed through the air due to off-gasing from the waste drums, from the release of assumed contamination on the outside surface of the drums, from accidental spill, or as a result of a fire.

If a release occurs, the air transport pathway presents the most rapid and pervasive dispersion mechanism whether the release occurs above or below ground. Deposition of radioactive particulates from airborne releases may also result in contamination of soils and surface water. The contribution of surface contamination to total radiological exposure is included in the AIRDOS-EPA model.

Based on extensive WIPP site characterization data and analyses performed for the draft FSAR, airborne releases are identified as the principal potential environmental pathway. For routine operations, air concentrations and surface deposition levels are calculated, using annual average site meteorologic conditions and postulated airborne releases, in all directions and at various distances from the WIPP. Radiological exposures to members of the public are calculated by summing the exposures from all potential pathways.

Accidental releases are assessed similarly, except that accident scenarios assume stable meteorological conditions which allow little dispersion of the release in order to estimate a maximum resulting hypothetical dose-to-man. Receptors for accident assessments are assumed to remain at the center-line of the release plume for the duration of each postulated accident.

Liquid Pathway. Liquid releases directly to ground water or surface water operations are not credible. Waste handling operations are conducted inside the Waste Handling Building or the underground repository. The waste does not contain free liquids. Any liquids containing radioactive materials that may be generated onsite operations will be contained, collected, and solidified in the Waste Handling Building. As such, no radioactive liquids are available for release during the operating life of the facility.

Pathways to surface water are not present even in the absence of any liquid waste effluents from the WIPP site. No major surface-water bodies exist within a 10-mile radius of the WIPP facility. The Pecos River is located 14 miles west of the site. The WIPP surface structures are approximately 500 ft above the river bed and over 400 ft above the 100-year flood plain.

Soil Pathway. A third pathway commonly considered in risk assessments is through direct releases to soil. All WIPP waste is containerized, handled within the Waste Handling Building and emplaced in rooms mined 2,150 ft below the ground surface. By the nature of the operations, there is no credible mechanism for direct release to soil.

Dose Calculation Modeling. This SEIS and the FEIS identify release of airborne radioactive particulates from the Waste Handling Building and the underground ventilation exhaust shaft as the most significant migration pathway arising from WIPP operations. A modified version of the computer code AIRDOS-II was used to calculate doses from radionuclide releases reported in the FEIS. AIRDOS-EPA, a modification of the AIRDOS-II computer code model (Moore et al., 1979), is used in current analyses to estimate off-site environmental concentrations and radiation doses associated with the atmospheric release of radionuclides in routine and accidental release assessments. Most of the input parameters which characterize the area surrounding the site or the radionuclides released are identical for routine and accidental releases. Other input, such as the amount of radioactivity released (the source term) and the meteorological assumptions, are specific to the release scenario. An overview of AIRDOS-EPA is included in Appendix F.

The AIRDOS-EPA computer code estimates the radiation dose to man due to the postulated atmospheric release of radionuclides from the WIPP. The area surrounding the site is modeled as a 50-mile radius circular grid system with the release point located at the center. For routine release assessment, annual average meteorological conditions are used to calculate exposures to the 50-mile radius population and to a theoretically maximally exposed individual. For accidental exposure assessment, meteorological conditions are postulated to result in a maximum dose at each reactor location. These meteorological conditions (windspeed, atmospheric stability class, and direction) are assumed to prevail for the duration of the accident and plume spread of the release is limited to 22.5°. The ground level concentration of airborne radioactivity at the center-line of the plume is used for these accident assessments.

Estimates of routine and accidental radiological releases and subsequent dose calculations for projected WIPP operations are taken from the draft FSAR (DOE, 1988c). As discussed above, calculations of radiological releases in the FSAR use source terms expressed as PE-Ci rather than specific radionuclide activities as used in the FEIS. Since there are no liquid release pathways from the site during operations, all releases evaluated for the WIPP, both routine and accident-related, are assumed to be airborne.

In assessing the radiological impacts of routine operations and accident scenarios, all particulates released from the Waste Handling Building pass through HEPA filters and are assumed to be of a respirable site. The respirable range is represented by a particle with a 1.0-micron, aerodynamic-equivalent diameter (AED) and a HEPA filter removal efficiency of 99.9 percent is assigned to each HEPA filter stage. This is a conservative assumption, since these filters are designed to remove even smaller particles, 0.3 micron AED, at an efficiency of 99.97 percent. Releases from the underground storage area are not filtered during routine operations since the filters are bypassed to prevent clogging with salt dust. In the event that a release is detected underground, all underground ventilation exhaust is designed to pass through two HEPA filters in series. However, in an attempt to bound the reasonably foreseeable impacts of the proposed action the ventilation system is assumed to be inoperable and result in an unfiltered release.

Ecological Consequences of Radiological Impacts. Radiological releases can also impact terrestrial and aquatic ecosystems. Exposures from estimated radiological releases to the ecosystem are compared to background levels to determine incremental increases. If releases and exposures are within naturally-occurring variations in background radiation levels, the impacts of the releases on the ecosystem will not be measurable. In general, ecosystem species, particularly plants, can endure higher exposures than those determined for human health protection.

Waste Retrieval. The FEIS (Subsection 8.10) did not provide a quantitative dose assessment of waste retrieval. In 1987, a mock retrieval demonstration for waste was performed at the WIPP using similar but non-radioactive containers to simulate CH TRU waste. The retrieval demonstration plan and a time-line dose assessment based on video recordings of the mock-up retrieval were documented in Westinghouse (1988a).

Routine retrieval operations involving both drummed and boxed waste were simulated in the demonstration. Although container failures are not expected during the test phase, potential radiation exposure estimates for failed and contaminated container retrieval were also obtained by evaluating retrieval and overpacking operations. The mock-up data were used to calculate the average crew dose per container for clean and contaminated boxes and drums. This crew dose was divided by the number of workers (16 waste handlers and eight health physics technicians) to obtain an average worker dose for retrieval of containers. Dose impacts associated with retrieval were evaluated for retrieval of clean containers and for a scenario where 5 percent of the containers were contaminated. Estimated retrieval doses were based on receipt of 10 percent of the total waste volume during the five-year test phase. Public risk estimates for waste retrieval activities assume the waste containers remain intact throughout the test phase and the subsequent, assumed, 10-year retrieval period.

If a decision to retrieve waste is made at the end of the test phase, a contamination control area would be established in waste retrieval chambers during waste retrieval operations. Airflow in the control area would be maintained such that workers remain upstream of the working face of the waste stack. Current plans are to continuously filter area exhausts through a single HEPA filter, reducing the concentration of particulates released to the underground storage exhaust shaft by a factor of 1000 before release to the atmosphere.

5.2.3.3 Routine Operational Radiological Releases and Exposures. Routine releases of radionuclides to air and resultant radiological exposures to workers and the public are discussed in this section. Possible public health and ecological consequences from such routine releases are evaluated in Subsection 5.2.3.5 Exposures are based on inhalation and direct exposure pathways as well as secondary pathways resulting from deposited material These secondary pathways include consumption of contaminated food and immersion in contaminated water.

Routine Radiological Releases During Facility Operations. Routine Releases–Proposed Action. Small amounts of radioactivity may be released during normal handling and storage operations. Potentially contaminated air will be exhausted from the Waste Handling Building and the Exhaust Shaft. Releases during routine operation are estimated using the current WIPP design (DOE, 1988c). Radioactive releases during the normal waste handling are estimated using an equivalent throughput of 22,000 drum per year (i.e., a projected 10 percent of the design capacity during the test phase) and assuming a throughput of approximately 49,500 drum equivalents of CH TRU waste and 400 canisters of RH TRU waste annually during the subsequent 20-year Disposal Phase. Throughputs are based on transportation scenarios discussed in Subsection 5.4 and Appendix D.3 which assume the drums are filled to only about 80 percent of their total volume due to settling and/or activity or weight limits being reached prior to capacity limits.

The waste handling building exhaust will be continuously filtered through two stages of HEPA filters. The underground storage exhaust flows through HEPA filters only when air monitors in the storage area or the exhaust detect airborne radioactivity in excess of preset limits.

Surface contamination levels on waste containers may vary significantly. The WIPP Waste Acceptance Criteria permit surface contamination levels of up to 50 pCi/100 cm^2 of alpha-emitting isotopes and 450 pCi/100 cm^2 of beta/gamma-emitting isotopes. These overall levels of surface contamination are admissable under Department of Transportation regulations. However, the retrieval program at the Idaho National Engineering Laboratory indicates that most retrievably stored drums are free of surface contaminants (McKinley and McKinney, 1978). To be conservative, the draft FSAR upon which this SEIS assessment was based assumes that 10 percent of all drums and boxes received at the WIPP have the maximum permitted level of surface contamination. A resuspension factor of $1x10^{-5}$/m, as recommended by Sutter (1982), was used to account for resuspension of surface containments as a result of handling within the Waste Handling Building and in the underground storage area.

Drums and boxes require inspection for possible damage before shipment to WIPP because only undamaged containers may be shipped. However, this risk assessment assumes that 0.1 percent of the drums and boxes received are damaged and release radioactivity into the Waste Handling Building when the shipping containers are opened; that one percent of the radioactive content is spilled. The analysis assumes that the airborne activity will be generated during one shift, 250 days per year and the resuspension factor of $1x10^{-5}$/m is valid.

RH waste canisters (about 400 per year) will be decontaminated before shipment to the WIPP. However, the current risk assessment conservatively assumes that, upon receipt at the WIPP, 10 percent of the canisters carry surface contaminants at the maximum level permitted by the Waste Acceptance Criteria. It is further assumed that the above resuspension factor is appropriate for the Waste Handling Building and the underground storage area. It is postulated that 0.1 percent of the RH TRU waste canisters a year (at least one) are defective upon arrival at the WIPP; and, that 1 percent of their content is released in the hot cell before the defective canister is overpacked.

Using the projected composition of waste identified above, and assuming 99.9999 percent removal efficiency by the two-stage HEPA filters in the Waste Handling Building and no filtration of underground releases, the calculated annual average releases to the atmosphere from the WIPP are shown in Table 5.15.

Routine Exposures - Proposed Action. As discussed previously, airborne release of radioactivity is the only significant pathway of exposure to the public. The release quantities provided in Table 5.12 and average annual meteorological conditions are used to calculate potential exposures to members of the public from routine WIPP operations. Annual radiation exposures are estimated to the population within 80 kilometers (50 miles) of the WIPP facility and to a maximally exposed offsite individual at the point of highest annual average air concentration. The FEIS assumed the maximum exposed individual was located at the nearest residence, Mills (James) Ranch. Dose estimates to members of the public are included in Table 5.16.

Table 5.16 indicates that routine operations could result in about 2.7×10^{-5} and 7×10^{-5} rem/year committed effective dose equivalent to the maximum exposed adult individual during the Test and Disposal Phases, respectively. These individual doses are considerably less than limits established by EPA (1988). Population doses are calculated to be 3.0×10^{-2} and 9.8×10^{-2} person-rem/year collective committed effective dose equivalents (50-year dose commitment).

Radiation exposure to workers may result from direct (external) radiation and from inhalation of contaminated particles. The facility is designed to meet the DOE goal of limiting occupational exposure to 20 percent of regulatory standards as stated in DOE Order 5480.11 (DOE, 1988a). Also, administrative controls, such as personal dosimetry, health physics surveys and radiation protection procedures, together with the use of protective clothing and respiratory protection when needed, will reduce radiation exposure to individual workers to as low as reasonably achievable within the DOE limit of five rem (0.05 sievert) per year (DOE, 1988a). Annual occupational exposure estimates to the work force are provided in Table 5.17.

Routine Waste Retrieval Releases and Exposures. If the decision is made to retrieve the emplaced TRU wastes, there will be certain radiological releases and exposures associated with retrieval. The assumptions used to assess radiation exposures to workers during waste retrieval activities are discussed above. Routine releases are not anticipated because waste containers are designed to maintain their structural integrity for at least 25 years. Occupational exposures were estimated from video recordings made during the mock retrieval demonstration for CH TRU waste (WEC, 1988a). Time-line studies were to estimate length of exposures and total doses. Potential doses were

TABLE 5.15 Routine radionuclide releases to the WIPP environment during the Proposed Action (total activity in curies/year)

	Proposed Action					
	Test Phase[a]		Disposal Phase[b]		Alternative Action[c]	
Isotope	WHB[d]	SE[e]	WHB	SE	WHB	SE
Co-60			7.4×10^{-12}	3.5×10^{-5}	7.4×10^{-12}	3.5×10^{-5}
Sr-90			2.2×10^{-10}	1.0×10^{-3}	2.2×10^{-10}	1.0×10^{-3}
Ru-106			1.5×10^{-12}	7.2×10^{-6}	1.5×10^{-12}	7.2×10^{-6}
Sb-125			4.8×10^{-14}	2.3×10^{-7}	4.8×10^{-14}	2.3×10^{-7}
Cs-137			1.9×10^{-10}	8.8×10^{-4}	1.9×10^{-10}	8.8×10^{-4}
Ce-144			1.5×10^{-11}	6.9×10^{-5}	1.5×10^{-11}	6.9×10^{-5}
Th-232	7.5×10^{-18}	3.5×10^{-11}	1.7×10^{-17}	8.0×10^{-11}	1.9×10^{-17}	8.8×10^{-11}
U-233	3.4×10^{-13}	1.6×10^{-6}	8.0×10^{-13}	3.8×10^{-6}	8.8×10^{-13}	4.2×10^{-6}
U-235	7.1×10^{-16}	3.3×10^{-9}	1.2×10^{-13}	5.7×10^{-7}	1.2×10^{-13}	5.7×10^{-7}
U-238	1.0×10^{-16}	4.9×10^{-10}	1.0×10^{-14}	4.8×10^{-8}	1.0×10^{-14}	4.8×10^{-8}
Np-237	3.4×10^{-16}	1.6×10^{-9}	7.6×10^{-16}	3.6×10^{-9}	8.5×10^{-16}	4.0×10^{-9}
Pu-238	2.8×10^{-11}	1.3×10^{-4}	1.0×10^{-10}	4.8×10^{-4}	1.1×10^{-10}	5.1×10^{-4}
Pu-239	2.5×10^{-11}	1.2×10^{-4}	1.0×10^{-10}	4.8×10^{-4}	1.1×10^{-10}	5.0×10^{-4}
Pu-240	7.4×10^{-12}	3.5×10^{-5}	3.1×10^{-11}	1.5×10^{-4}	3.3×10^{-11}	1.6×10^{-4}
Pu-241	6.6×10^{-10}	3.1×10^{-3}	2.0×10^{-9}	9.4×10^{-3}	2.1×10^{-9}	1.0×10^{-2}
Pu-242	1.4×10^{-15}	6.7×10^{-9}	5.7×10^{-15}	2.7×10^{-8}	6.1×10^{-15}	2.9×10^{-8}
Am-241	3.7×10^{-11}	1.8×10^{-4}	8.8×10^{-11}	4.2×10^{-4}	9.8×10^{-11}	4.6×10^{-4}
Cm-244	1.1×10^{-13}	5.1×10^{-7}	1.3×10^{-12}	6.2×10^{-6}	1.4×10^{-12}	6.4×10^{-6}
Cf-252	2.7×10^{-14}	1.2×10^{-7}	1.9×10^{-12}	8.8×10^{-6}	1.9×10^{-12}	8.8×10^{-6}
Total	7.6×10^{-10}	3.6×10^{-3}	2.8×10^{-9}	1.3×10^{-2}	2.9×10^{-9}	1.4×10^{-2}

[a] Based on annual throughput equivalent to about 22,000 CH drums.
[b] Based on annual throughput equivalent to about 49,500 CH drums and 400 RH canisters.
[c] Based on annual throughput equivalent to about 55,000 CH drums and 400 RH canisters.
[d] WHB = Waste Handling Building.
[e] SE = Storage exhaust.

TABLE 5.16 Annual radiation exposure to the public from routine operations during the Proposed Action

Activity	Proposed Action Test Phase	 Disposal Phase	Alternative Action
Population[a] (person-rem)	2.7×10^{-2}	8.9×10^{-2}	9.4×10^{-2}
Population background (person-rem)	$9.6 \times 10^{+3}$	$9.6 \times 10^{+3}$	$9.6 \times 10^{+3}$
Maximum[b] individual (rem)	1.9×10^{-5}	6.3×10^{-5}	6.7×10^{-5}
Individual background (rem)	1.0×10^{-1}	1.0×10^{-1}	1.0×10^{-1}

[a] 50-year committed effective dose equivalent to population within 50 miles.
[b] 50-year committed effective dose equivalent at point of maximum air concentration.

TABLE 5.17 Annual occupational radiation exposure from routine operations during the Proposed Action[a] (person-rem/year)

Activity	Proposed Action Test Phase	 Disposal Phase	Alternative Action
Direct Radiation	7.9	17.9	19.8
Inhalation of Airborne Contaminants[b]	0.29	0.87	0.93
Total	8.19	18.77	20.73

[a] Exposures are total exposures to the entire waste handling crew.
[b] 50-year committed effective dose equivalent for one year of exposure.

determined for the total work crew and for an average individual worker, and the resultant dose estimates assumed the exposure period is 10 years.

The mock-up evaluation also estimated doses due to handling waste containers with surface contamination. No mechanism for the release of contaminants in the waste storage areas has been identified. However, consistent with the assumptions made in the dose assessments for facility operations, it is assumed that five percent of the waste containers were found to be contaminated and require overpacking. Estimated occupational exposures for waste retrieval activities are shown in Table 5.18.

The exposure as a result of retrieval operations to an individual receiving the maximum off-site exposure is calculated the same as for waste emplacement exposure. However, annual releases associated with retrieval are much less than routine emplacement because the retrieval process is projected to be much slower than emplacement, resulting in fewer containers being handled annually. Any releases are reduced by a factor of 1000 due to the HEPA filter in the contamination control area. These exposure estimates are also very low as shown in Table 5.18.

5.2.3.4 Accidental Radiological Releases and Exposures. This subsection assesses the potential radiological releases and exposures associated with postulated accident scenarios for WIPP operations. Accident scenarios are formulated and evaluated to assess their potential consequences. Environmental and health consequences of postulated accidents are summarized below. Most of the accidents during the WIPP's operating lifetime are expected to be industrial in nature and not unique to a facility handling radioactive material and will not result in releases of radioactive material.

Operational accident scenarios were developed and analyzed in both the FEIS (Subsection 9.5) and this document (Appendix F). The FEIS assessment included several accident scenarios involving both CH and RH waste. Of these accident scenarios, four involving CH and two involving RH waste were assumed to be "limiting" and were analyzed in detail. This SEIS analyzes the 10 CH and 6 RH waste accident scenarios which are also described in Appendix F of this SEIS.

Projected Accidental Releases. The accident scenarios were formulated from an examination of WIPP process operations, design basis inventories, and controls of radiological/hazardous materials. No pathways were identified whereby accidental releases of liquids to the environment might occur. Airborne release is the only significant pathway for accidental exposure to the public. Accidental releases of soluble and insoluble forms of waste constituents were assessed.

Accident scenarios are developed by following the course of a typical waste container from off-loading in the Waste Handling Building receiving area to final storage in the waste storage area, and by reviewing waste handling procedures. The normal operation of waste handling equipment, such as forklifts and hoists, was studied to determine how equipment misuse or failure could result in a breach of the waste containers. Tables 5.19 and 5.20 list accident scenarios for this SEIS and their frequencies for CH and RH waste-handling activities, respectively.

TABLE 5.18 Estimated occupational and maximum off-site individual radiation exposures for routine CH waste retrieval activities [a]

	Case I[b]	Case II[c]	
	Clean drums	95% Clean drums	5% contaminated drums
Average crew dose/container (mrem)	0.7	0.7	1.7
Total number of containers	110,000	104,500	5,500
Total crew	24	24	24
Total crew dose (person-rem)	77.0	73.2	9.4
Average dose/ worker (mrem per	321	305	39

5	5-50	Table 5.18	In Case II, 5% contaminated drums column: last number, 3.0×10^{-9} should read 6.6×10^{-6}.

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[a] References (McKinley and McKinney, 1978).

[b] Case I assumes all drums are free of surface contamination.

[c] Case II assumes 95 percent of drums are free of surface contaminants and 5 percent of drums have surface contamination levels at levels permitted by the waste acceptance criteria.

5	5-50	Table 5.18	Footnote [e] should read: "Average 50-year committed effective dose equivalent for each of ten years to a maximum individual located at the site boundary, assuming release of surface contamination levels as discussed in Subsection 5.2.3 for calculating release from routine emplacement activities."

TABLE 5.19 Accident scenarios involving contact-handled waste[a]

Area	Accident ID	Estimated frequency	Possible accident scenario
5 5-51	Table 5.19	In the Estimated frequency Column: first entry "INF," should read "MF."	PACT-II drops from transporter
Offloading/loading	C1	MF	Vehicle collision in offloading area
Inventory/preparation	C2	MF	Drum(s) drop from forklift
	C3	MF	Drum(s) punctured by forklift
Underground storage	C4	MF	Transporter hits pallet
	C5	MF	Drum(s) drop from forklift
	C6	MF	Drums punctured by forklift or other equipment
Inventory/preparation	C7	LIM(NE)	Spontaneous ignition within a drum
Hoist loading areas	C8	LIM(NE)	A loaded hoist cage drops down waste handling shaft
Underground storage	C9	LIM(NE)	Diesel fire in storage array underground
	C10	LIM	Spontaneous ignition with a drum

MF = Moderate Frequency (assumed to occur annually).
INF = Infrequent (assumed to occur once during the life of the facility).
LIM = Limiting (assumed not likely to occur during the life of the facility).
NE = Not evaluated per DOE policy (DOE, 1988d).

[a] Source: draft FSAR (DOE, 1988c).

TABLE 5.18 Estimated occupational and maximum off-site individual radiation exposures for routine CH waste retrieval activities [a]

	Case I[b]	Case II[c]	
	Clean drums	95% Clean drums	5% contaminated drums
Average crew dose/container (mrem)	0.7	0.7	1.7
Total number of containers	110,000	104,500	5,500
Total crew	24	24	24
Total crew dose (person-rem)	77.0	73.2	9.4
Average dose/ worker (mrem per year)[d]	321	305	39
Maximum offsite individual dose (mrem)[e]	-----	-----	3.0×10^{-9}

[a] References (McKinley and McKinney, 1978).

[b] Case I assumes all drums are free of surface contamination.

[c] Case II assumes 95 percent of drums are free of surface contaminants and 5 percent of drums have surface contamination levels at levels permitted by the waste acceptance criteria.

[d] erage millirem per year for each of 10 years.

erage 50-year committed effective dose equivalent for each of ten years to a ximum individual located at the site boundary, assuming 1 percent release of the ne surface contamination levels as the FSAR postulates for calculating release from tine emplacement activities.

TABLE 5.19 Accident scenarios involving contact-handled waste[a]

Area	Accident ID	Estimated frequency	Possible accident scenario
Radiological control area outside of WHB	CO	INF	TRUPACT-II drops from transporter
Offloading/loading	C1	MF	Vehicle collision in offloading area
Inventory/preparation	C2	MF	Drum(s) drop from forklift
	C3	MF	Drum(s) punctured by forklift
Underground storage	C4	MF	Transporter hits pallet
	C5	MF	Drum(s) drop from forklift
	C6	MF	Drums punctured by forklift or other equipment
Inventory/preparation	C7	LIM(NE)	Spontaneous ignition within a drum
Hoist loading areas	C8	LIM(NE)	A loaded hoist cage drops down waste handling shaft
Underground storage	C9	LIM(NE)	Diesel fire in storage array underground
	C10	LIM	Spontaneous ignition with a drum

MF = Moderate Frequency (assumed to occur annually).
INF = Infrequent (assumed to occur once during the life of the facility).
LIM = Limiting (assumed not likely to occur during the life of the facility).
NE = Not evaluated per DOE policy (DOE, 1988d).

[a] Source: draft FSAR (DOE, 1988c).

TABLE 5.20 Accident scenarios involving remote-handled waste[a]

Area	Accident ID	Estimated frequency	Possible accident scenario
Receiving	R1	MF	Crane strikes shipping cask
	R2	INF	Shipping cask drops from crane
	R3	INF	Shipping cask drops in the cask preparation area
Hot cell	R4	INF	RH waste canister drops from hot cell into transfer cell
Hoist cage loading area	R5	LIM(NE)	A loaded hoist cage drops down waste handling shaft with a canister of RH TRU waste
Underground	R6	LIM	Fire in RH waste storage area

MF = Moderate Frequency (assumed to occur annually).
INF = Infrequent (assumed to occur once during the life of the facility).
LIM = Limiting (assumed not likely to occur during the life of the facility).
NE = Not evaluated per DOE policy (DOE, 1988d).

[a] Source: draft FSAR (DOE, 1988c).

The frequency category of an event was derived from the operating experience of similar facilities when such data are available. Conservative engineering judgment was used to classify events if relevant historical information was not available. Incidents of moderate frequency were assumed to occur once a year. Infrequent incidents were assumed to occur once during the operation of the WIPP. Limiting incidents were those that are not expected to occur during the life of the facility but were included in the analysis to bound the reasonably foreseeable release of radioactivity. Accidents whose probability of occurrence is less than 1×10^{-6} per year are not considered to have a reasonable probability of occurring and per DOE/AL Order 5481.1B (DOE, 1988d); their consequences were not assessed.

The source terms used in the analyses were based on the inventory information discussed in SEIS Appendix B. For events of moderate frequency, i.e., those projected to occur once per year, the average radionuclide content of the waste package was assumed to be available for release. For limiting accidents, the maximum allowable curie content of a waste package (1000 PE-Ci) was assumed available for release. The WIPP WAC limit the maximum amount of respirable particulates (those less than 10 microns in diameter) in a waste container to one percent by weight. However, to ensure conservatism when dealing with a single or few containers, this respirable fraction was assumed to contain 5 percent of the waste's radioactivity. Furthermore, due to the lack of specific information concerning the particle size distribution, an activity median aerodynamic diameter of 1.0 micron has been assumed. Detailed accident descriptions and assumptions about releases are provided in Appendix F. Table 5.21 shows projected releases from accidents postulated in the SEIS. Underground releases in the FEIS were assumed to be reduced by a HEPA filter removal factor of 1×10^{6}. For conservatism, data in Table 5.21 do not assume releases from the underground repository will be filtered prior to release to the atmosphere.

Projected Accidental Exposures Proposed Action. Exposures are assessed in terms of the radiation dose to a receptor. The receptor for occupational dose is a worker near the accident, while the receptors for public exposure are located outside of the secured area.

Occupational exposure estimates are also provided in Table 5.21. They are conservatively estimated, since workers will normally be located in the "up-stream" airflow of a waste handling area. The maximum exposure to a single worker is estimated to be 9.2 rem which is well within DOE guidance for accident exposure to individuals in the public (DOE, 1988e). Workers will be trained to respond to any unusual occurrence by leaving the area immediately and reporting the event so that evaluation and cleanup can begin promptly.

Doses to individuals located outside the facility boundary (aboveground and away from the physical location of the postulated accident) are also assessed. An accidental exposure to radioactivity can occur via three major routes: inhalation of contaminated air, external exposure from immersion in contaminated air, and exposure from contaminated ground surfaces. Less important routes for the radionuclides under consideration include ingestion of contaminated food and water and immersion in contaminated water. The maximum exposure is estimated to be 1.1 rem which is also well within DOE siting criteria for accidental releases in DOE Order 6430.1A (DOE, 1988f).

TABLE 5.21 Radiation releases and exposure from projected accidents during WIPP facility operation

Accident	Description	Release (Curies[a,b])	Occupational (rem)	Maximum indiviudal[a,c] (rem)
<u>SEIS</u>[d]				
C2	WHB,[e] 1 drum, drop, CH	1.6×10^{-10}	5.2×10^{0}	3.5×10^{-10}
C3	WHB, 3 drums, breach, CH	2.9×10^{-10}	7.5×10^{0}	6.4×10^{-10}
C4	UG,[f] 1 drum, drop, CH	1.3×10^{-4}	5.2×10^{0}	2.9×10^{-4}
C6	UG, 3 drum, breach, CH	2.3×10^{-4}	9.2×10^{0}	5.1×10^{-4}
C10	UG, 1 drum, ignition, CH	5.0×10^{-1}	None	1.1×10^{0}
R4	Canister drop, RH hot cell	5.0×10^{-10}	None	1.1×10^{-9}

[a] SEIS estimated releases and exposures due to underground scenarios are not reduced by a factor of 1×10^6 and does not take credit for HEPA filters as was done for the FEIS.

[b] SEIS releases are expressed as PE-Ci.

[c] Located at Mills Ranch.

[d] From draft FSAR, Tables 7.3-1 and 7.3-2 (DOE, 1988c).

[e] WHB = Waste Handling Building.

[f] UG = Underground Storage Area.

5.2.3.5 Human Health and Environmental Consequences of Radiological Releases. Estimated releases of and consequent exposures to radioactive materials in the TRU wastes are related to potential risks to human health and the environment. The FEIS calculated radiological exposures for human populations and discusses the potential health effects associated with those exposures. In this assessment, risks to human health are expressed as an increase in the risk of fatal cancers due to radiological exposure.

Consequences of Facility Operations. It is assumed that management and control systems operate as designed and that normal operations remain within established limits in the assessment of consequences related to routine operational releases and exposures resulting from WIPP operations. Human health risks presented in Tables 5.22 and 5.23 for routine and accidental exposures, respectively, are based on dose estimates discussed in SEIS Subsections 5.2.3.3 and 5.2.3.4. A discussion of risk estimation and regulatory guidance concerning risk levels are provided in SEIS Subsection 5.2.2.1.

It is estimated that 2.3×10^{-3} and 5.3×10^{-3} excess fatal cancers will occur in the exposed worker population from routine operations during the Test and Disposal Phases respectively. An estimated 8.4×10^{-6} and 2.7×10^{-5} fatal cancers are projected in the population within 50 miles of the WIPP annually due to normal operations during the Test and Disposal Phases throughout the total population of 95,810. The maximum individual is estimated to have 5.3 and 18 chances per billion of contracting a fatal cancer during the Test and Disposal Phases due to normal operations.

Table 5.23 shows health risks associated with radiation exposures during the postulated accidents. Occupational workers will incur an estimated 26 in 10,000 (2.6×10^{-3}) excess risk of contracting a fatal cancer. Health risks associated with the exposure to an individual at the nearest residence following the worst case accident is about 3.1 in ten thousand (3.1×10^{-4}). If credit is taken for filtering underground releases by the HEPA filtration, the risk drops by a factor of one million.

Potential ecological consequences are based on the predicted off-site radionuclide concentrations in air. Annual off-site air concentrations, assumed to be Pu-239, of 5.1×10^{-21} picocuries/m^3 will result in a soil deposition of 7.5×10^{-3} picocuries/m^2. The average level of plutonium in soils is 1.4 picocuries/m^3, which is attributable to fallout from atmospheric testing of nuclear weapons. The radiation exposures to the ecosystem by routine and accidental radiological releases are orders of magnitude less than radiological background levels.

Consequences of Waste Retrieval. Radiological exposures from routine and accidental releases during waste retrieval are estimated to be the same or less than exposures during waste emplacement. The associated human health and ecological consequences would be in the same range.

TABLE 5.22 Human health risks associated with routine radiological releases from WIPP operations during the Proposed Action[a,b,c]

Occupational Risk

Activity	Proposed Action		Alternative Action
	Test Phase	Disposal Phase	
Facility operations	$2.3\mathrm{x}10^{-3}$	$5.3\mathrm{x}10^{-3}$	$5.8\mathrm{x}10^{-3}$
Waste retrieval	$2.3\mathrm{x}10^{-3}$	-----	-----
Current risk of fatal cancers	$2.2\mathrm{x}10^{-1}$	$2.2\mathrm{x}10^{-1}$	$2.2\mathrm{x}10^{-1}$

Total Population

Activity	Proposed Action		Alternative Action
	Test Phase	Disposal Phase	
Facility operations	$7.6\mathrm{x}10^{-6}$	$2.5\mathrm{x}10^{-5}$	$2.6\mathrm{x}10^{-5}$
Waste retrieval	$7.6\mathrm{x}10^{-6}$	_____	_____
Current risk of fatal cancers	$2.2\mathrm{x}10^{-1}$	$2.2\mathrm{x}10^{-1}$	$2.2\mathrm{x}10^{-1}$

[a] Health risks are expressed as the number of excess fatal cancers estimated in the exposed population as a result of annual WIPP-related activities.

[b] Risk of contracting fatal cancer: $2.8 \mathrm{\ x\ } 10^{-4}$ fatalities/person-rem for each year of operation (BEIR, 1980).

[c] Annual health effects risk estimates for genetic effects would be somewhat less (a factor of 0.918) than the numbers presented in the table for cancer fatality risks.

TABLE 5.23 Human health risks associated with worst-case accidental radiological releases during WIPP operations[a]

	Occupational Risk[b,c]		
	Proposed Action[d]		
Activity	Test Phase	Disposal Phase	Alternative Action
Facility operations	2.6×10^{-3}	2.6×10^{-3}	2.6×10^{-3}
Waste retrieval	2.6×10^{-3}	--	--
Current risk of fatal cancers	2.2×10^{-1}	2.2×10^{-1}	2.2×10^{-1}

	Maximum Individual[b,c,e]		
	Proposed Action[f]		
Activity	Test Phase	Disposal Phase	Alternative Action
Facility operations	3.1×10^{-4}	3.1×10^{-4}	3.1×10^{-4}
Waste retrieval	3.1×10^{-4}	--	--
Current risk of fatal cancers	2.2×10^{-1}	2.2×10^{-1}	2.2×10^{-1}

[a] Annual health effects risk estimates for genetic effects would be somewhat less (a factor of 0.918) than the numbers presented in the table for cancer fatality risks.

[b] Health risks are expressed as the probability of an individual contracting a fatal cancer during their lifetime as a result of annual WIPP-related activities. Risks are expressed in exponential form; i.e., 1×10^{-4} is equivalent to one chance in 10,000.

[c] Risk of contracting fatal cancer: 2.8×10^{-4} fatalities/rem for each year of operation (BEIR, 1980).

[d] FSAR accident C6.

[e] At the site boundary from underground storage exhaust.

[f] FSAR accident C10.

5.2.4 Risk assessment and analysis of hazardous chemical environmental consequences of operations and possible retrieval at the WIPP

This section examines the potential environmental and human health impacts associated with the hazardous chemical constituents of TRU waste resulting from waste handling activities at the WIPP during the Test Phase and disposal operations. Impacts of chemical constituents were not considered in the FEIS (SEIS Subsection 10.2). This risk assessment identifies viable migration pathways and estimates potential chemical releases via each relevant migration pathway. Potential pathways of human and environmental exposure are also identified and exposures are estimated based on relevant chemical release scenarios. Finally, the ranges of risk associated with the exposure estimates are provided. A description of the general risk assessment methodology is provided in Section 5.2.3.1.

Routine operations at the WIPP, aboveground and underground, are considered in the assessment, consistent with the scope of the radiological analysis in the FEIS and in the SEIS Subsection 5.2.3 and Appendix F. Potential accident scenarios and associated hazardous chemical releases are also considered. The initial five-year Test Phase in the Proposed Action includes bin- and room-scale tests, including a maximum of 10 percent receipt of waste.

Subsection 5.2.4.1 describes the methodology used in the chemical risk assessment. Subsection 5.2.4.2 evaluates potential hazardous chemical release fractions and exposures that may be associated with routine operations. Subsection 5.2.4.3 addresses those potential risks resulting from a series of hypothetical accident scenarios. Subsection 5.2.4.4 identifies potential human health consequences associated with the estimates of chemical exposures. An analysis of the uncertainties affecting the risk estimates is presented in Subsection 5.2.4.5. Additional health, safety, and environmental concerns are addressed in a Final Safety Analysis Report (FSAR) (DOE, 1988c) for the WIPP which is being prepared in compliance with DOE Order 5481.1B (DOE, 1988d).

5.2.4.1 Hazardous Chemical Risk Assessment Methodology. The estimation of human health risks is a characterization of the general range of potential risks based on a selected set of assumptions. The precision of such estimates is limited by the quantity and quality of the available data. The waste-related chemical characterization data for this assessment are restrictive, with limited quantitative concentration data. The estimates resulting from a sparse data base such as the one relied on in this report should be considered relative and not absolute. In this assessment, uncertainties that result from insufficient analytical data on waste chemistry are mitigated by employing a series of conservative assumptions that yield ranges of extremes. This approach to managing uncertainties tends to overestimate risks rather than underestimate them.

The assumptions in the risk assessment result in a strong bias toward health protection. For example, in estimating occupational exposures from routine operations for the five-year Test Phase and for the 20-year operational period, workers were assumed to spend an eight-hour shift every work day at the points above and below ground identified as the locations of the highest chemical concentrations. As another example, a hypothetical residential receptor was placed at the site boundary at a point of maximum potential exposure and was assumed to be present at that location continuously for 20 years. The effects associated with such highly improbable conditions should be greater than the effects associated with more realistic scenarios.

Migration Pathways. The media through which hazardous chemicals may travel to reach potential receptor locations include air, ground and surface waters,and soil. Subsection 5.2.3 of this SEIS examines the viability of each pathway with regard to radionuclide releases and explains why, of these, air is the only credible pathway. The same arguments apply to potential pathways for hazardous chemical releases.

Evaluation of Waste-Related Chemical Data. CH TRU waste from the Rocky Flats Plant that is in retrievable storage at the Idaho National Engineering Laboratory and newly-generated wastes from the Rocky Flats Plant will contribute about 60 percent of the total inventory of TRU mixed waste to be emplaced in the WIPP (WEC, 1989). It was assumed that these wastes contain the estimated minimum and maximum total concentrations of hazardous chemicals present in currently-generated CH TRU waste from the Rocky Flats Plant (Table 5.24). As described in Subsection 3.1.1, these estimates are based on knowledge of the wastes or waste-generating processes. Weighted average concentrations have been calculated for these chemical components based on the total quantities of the various waste forms in which they occur. The derivation of weighted average concentrations was based on the product of the estimated maximum concentration of each chemical constituent in a waste form and the percentage of that waste form in the total inventory. The weighted average concentrations were then assumed to be present in all waste forms. For example, the waste form described as metal (Table B.3.1, Appendix B) comprises approximately 25.7 percent of the total quantity of the newly-generated CH TRU mixed waste reported by the Rocky Flats Plant. The weighted average concentrations are derived from the following formula:

$$C_a = [(C_1m_1)(C_2m_2)...(C_im_i)...(C_nm_n)]/m_T, \quad i = 1,...,n,$$

where

C_a = chemical-specific weighted average concentration,

C_i = chemical-specific concentration for the i^{th} waste form, $i = 1,...,n$,

m_i = chemical-specific mass for the i^{th} waste form, $i = 1,...,n$,

m_T = chemical-specific total mass for all waste forms.

The concentrations of chemicals calculated by the procedure described above were assumed to be present in every drum of CH TRU waste.

TABLE 5.24 Estimated concentrations of hazardous constituents in transuranic mixed waste from the Rocky Flats Plant [a]

Hazardous constituent	Minimum	Maximum	Weighted average
	mg/kg		
1,1,1-Trichloroethane	75	150,000	16,081
Trichloroethylene[b]	75	150,000	16,081
Carbon Tetrachloride	25	50,000	5,380
1,1,2-Trichloro-1,2,2-Trifluoroethane	75	50,000	5,644
Methylene Chloride	50	750	462
Methyl Alcohol	0	25	9
Xylene	0	50	19
Butyl Alcohol	0	10	4
Cadmium	0	10	4
Lead	0	1×10^6	265,739

[a] Rockwell International, 1988.

[b] No estimates were available on the total concentration of trichloroethylene. Based on knowledge of past industry practice, the concentration was assumed to be equivalent to that of 1,1,1-trichloroethane.

Past practices at the Rocky Flats Plant indicated that 1,1,1-trichloroethane was substituted for trichloroethylene in about 1975. Trichloroethylene was detected in the headspace gas of drums sampled at the Idaho National Engineering Laboratory (Clements and Kudera, 1985), therefore it was assumed to have the same total concentration in the waste as 1,1,1-trichloroethane and was included in the risk assessment. Based on the above considerations and the data limitations, five volatile organics and one metal were selected as representative of the chemical waste likely to be stored at the WIPP facility for these "representative" chemicals. Waste concentration data are most complete. Each is predicted to average greater than one percent of the waste by weight. The representative chemicals are:

- Carbon tetrachloride
- Methylene chloride
- 1,1,1-Trichloroethane
- 1,1,2-Trichloro-1,2,2-Trifluoroethane (Freon 113)
- Trichloroethylene
- Lead

Trichloroethylene, carbon tetrachloride and methylene chloride are considered to be potential human carcinogens, while 1,1,1-trichloroethane and Freon 113 are known to produce adverse somatic effects when present in sufficient concentrations. Appendix G provides a more detailed discussion of the toxic properties of these chemicals.

No analytical data were available on the concentrations of metals in TRU waste. However, lead is the most prevalent metal by both weight and volume (WEC, 1989). Other metals reported as potentially present in TRU mixed wastes, based on process knowledge and/or knowledge of the wastes, are included in Table 5.25.

Particulate releases of heavy metals during routine operations are assumed to be insignificant due to:

- The strict WAC certification requirements and operational procedures to assure no radioactive contamination exists on the surfaces of containers.

- The nature of the metal-containing waste. Metal in the waste, most of which is lead in monolithic forms, is present in bricks and shielding rather than the particulate form (WEC, 1989). The primary sources of other metals are in the form of sheets, rods, or parts of equipment.

- The elaborate HEPA filtration system designed for the ventilation system at the WIPP.

For certain hypothetical accident events, particulate release of lead, the representative metal, was evaluated.

TABLE 5.25 Hazardous chemical constituents reported in CH TRU mixed waste for which no estimates on concentrations are available[a]

Metals[b]	Organics[b]
Arsenic	Tetrachlorethylene
Barium	Acetone
Chromium	Toluene
Mercury	
Selenium	
Silver	
Beryllium	

[a] Information obtained from the "WIPP RCRA TRU Mixed Characterization Data Base," (WEC, 1989).

[b] Based on knowledge of the wastes and/or the processes that generate them.

Because of the types of hazardous chemicals and the physical waste forms associated with the chemical components of RH TRU mixed waste, no releases of hazardous chemicals during routine operations or accidents were postulated. RH TRU mixed waste does not contain RCRA-regulated volatile organic compounds (WEC, 1989). Similar to CH TRU mixed waste, the predominant metal was lead that is present primarily as shielding. RH TRU process wastes (i.e., sludges) will be solidified (e.g., vitrified or cemented) prior to shipment to the WIPP. Routine releases of hazardous chemicals from RH TRU mixed wastes were not considered as reasonably foreseeable events. The only accident considered in the FSAR (SEIS Appendix F) for RH TRU waste was the release of radioactive particulates from a canister that was dropped from the hot cell into the transfer cell. Hazardous chemicals are not expected to be associated with a particulate fraction in RH TRU waste.

Estimation of Release Fractions. Although the total estimated concentrations of chemicals in the waste were needed to identify those chemicals that were used as representative of the waste to be received at the facility, additional consideration must be given to estimating the quantity of each chemical potentially available for release to the environment. Chemical, biological, and radiological processes that occur in the waste are important factors in this regard since they influence the types of chemicals released and their release rate.

Volatilization and degradation of organic compounds are the two primary processes that produce gases in drums of TRU waste. The volatilization of organic constituents in mixed waste is a function of their vapor pressure in relation to the ambient temperature of the matrix in which they occur. Radiolytic and microbial degradation of TRU wastes generate primarily hydrogen, carbon dioxide, and oxygen. The concentration of all gases in any particular drum of waste is a function of the various processes occurring at a given time.

Information obtained from studies conducted at the Idaho National Engineering Laboratory on gas generation rates (Clements and Kudera,1985) provides the basis for estimating the concentration of selected volatile organics in the waste drums during the Test Phase and disposal operations at the WIPP and for postulating release fractions. The studies were conducted as part of a TRU waste sampling program undertaken by the Idaho National Engineering Laboratory to evaluate various types of TRU waste received from the Rocky Flats Plant for temporary storage. A total of 13 waste forms (combustibles, sludges, metals, etc.) were randomly selected from those that were expected to comply with the requirements of the WIPP WAC. This was done as part of the study to verify the effectiveness of certification procedures. The nature and objectives of the study also necessitated that the drums have airtight seals to allow accurate measurement of gas generation rates, gas concentrations, and void volumes. Under this condition, the headspace gases of 172 drums were sampled and analyzed.

The "void volume" is the total volume of a drum occupied by gases. The average void volume within the drums sampled was calculated to be 147.26 liters. The average void volume was used to calculate the total grams of a hydrocarbon in the gas phase of each drum. Since 55 gallons is equal to approximately 208 liters, it is assumed that more than half of each drum is comprised of air and other gases.

The average concentrations of the selected hydrocarbons in the headspace of the drums are given in Table 5.26. Although it was assumed that this concentration of gases is present in every drum, analytical results from Clements and Kudera (1985) indicated that the hydrocarbons are often below detection limits (Table 5.27). Thus, the use of these average concentrations represents a bounding case assumption.

It should be noted that headspace gas concentrations cannot be directly correlated to the total concentrations in the waste because of the complex nature of the vapor-waste equilibria distribution of the organic compounds. For example, in waste forms containing bound water (i.e., solidified sludges), the vapor pressure of the organics is reduced appreciably. The volatile organic compounds present in the waste include compounds that exert appreciable vapor pressures at ambient temperatures expected in the WIPP (e.g., Freon 113 and methylene chloride). The vapor pressure of a pure compound is generally not completely exerted when the compound is in a combined form with other substances. Clements and Kudera (1985) observed a decrease in the concentrations of volatile organics in the headspace of drums containing combustibles. Wastes were vented through a carbon composite filter for thirteen weeks and then purged and sealed, indicating that the source term of the organics was limited. The data from Clements and Kudera (1985) represent the concentrations of hydrocarbons that may potentially be released to the air while the waste is being managed.

Waste containers for shipment to the WIPP will be vented through a carbon composite filter to prevent pressurization of the drums due to hydrogen gas generation during transportation and placement. To evaluate risks associated with the chemical component of the waste during the Test Phase and throughout 20 years of disposal operations, a release rate of gas from each drum through the filter was derived from data obtained through experiments conducted by Westinghouse Electric Corporation (WEC, 1988b). The emission rates (Table 5.28) were estimated by relating the diffusion rate of hydrogen to these hydrocarbons. The diffusion coefficients of the volatile organics were computed by multiplying the hydrogen diffusion coefficient by the square root of the ratio of hydrogen to the specific gas molecular weight. No credit was taken for any adsorption of the organics on the carbon composite filters. It was also assumed that the hydrocarbons were emitted at a constant rate. In reality, the emission rate of volatile organic compounds will decrease over time as their concentrations in the waste container decrease.

Potential Releases of Hazardous Chemicals. Potential releases to air during the Test Phase and Disposal Phase operations below ground were modeled for the five-year and 20-year period, respectively, based on the amount of waste projected to be emplaced in the facility during these times. Each underground storage room has a capacity of approximately 6,000 55-gal drums. During the Test Phase, the WIPP will potentially accept up to 110,000 drum-equivalents. This represents about 10 percent of the 6.2 million cubic feet of total repository capacity for CH TRU waste. Because this is the Test Phase for the facility, the storage rooms may not be back-filled. If the decision is made after the Test Phase to continue the project into the Disposal Phase, these rooms will then be backfilled and sealed. After the Test Phase, the facility is expected to receive an average of 49,500 drum-equivalents of CH TRU waste per year. A room will be sealed immediately after its capacity is reached, or about once every two months.

TABLE 5.26 Average concentration of selected hydrocarbons in the headspace of TRU waste drums[a]

Hydrocarbon	Average concentration (g/l)[b]
Carbon Tetrachloride	1.9×10^{-3}
Methylene Chloride	0.5×10^{-3}
Trichloroethylene	7.0×10^{-4}
1,1,1-Trichloroethane	13.2×10^{-3}
1,1,2-Trichloro -1,2,2-Trifluoroethane	1.2×10^{-3}

[a] Clements and Kudera, 1985.

[b] g/l: grams per liter

TABLE 5.27 Number of drums containing detectable quantities of selected organics in TRU waste from the Rocky Flats Plant[a]

Volatile organic compound[b]	Number of drums containing detectable quantities	Percentage of drums containing detectable quantities[c]
Carbon Tetrachloride	12	7
Methylene Chloride	21	12
Trichloroethylene	29	17
1,1,1-Trichloroethane	91	53
Freon-113	11	6

[a] Clements and Kudera, 1985.

[b] Volatile organic compounds were selected based on available estimates of their total concentrations in waste from the Rocky Flats Plant (Rockwell, 1988).

[c] Percentages based on a total of 172 drums sampled.

TABLE 5.28 Average emission rates of selected hydrocarbons through the carbon composite filters of TRU waste drums

Hydrocarbon	Average emission rate (g/s)[a]
Carbon Tetrachloride	2.3×10^{-8}
Methylene Chloride	7.8×10^{-9}
Trichloroethylene	9.3×10^{-9}
1,1,1-Trichloroethane	9.3×10^{-9}
1,1,2-Trichloro-1,2,2-Trifluoroethane	1.4×10^{-8}

[a] g/s: grams per second

Therefore, the period of maximum potential exposure is assumed to be during the Test Phase because none of the rooms will be backfilled and sealed during this period.

Aboveground operations that may lead to potential releases are expected to occur in the Waste Handling Building (WHB). It is here that TRUPACT-IIs will be opened and the individual drums readied for emplacement in the underground storage rooms. Three TRUPACT-IIs (e.g., 42 drum-equivalents) were assumed to be present at all times in the WHB.

The following assumptions were employed in estimating potential releases of hazardous chemicals to air in the WHB and the underground storage area:

- Emissions from the waste drums occur at a constant and continuous rate until the available source is depleted.
- During the Test Phase, waste drums accumulate underground at the facility at the rate of 22,000 drums per year.
- During the Test Phase, individual underground storage rooms are filled on the first day of each year (i.e., on day one of year one, 22,000 drums arrive and begin the emission pattern described above; on day one of year two, another 22,000 drums arrive, etc.). At the beginning of the fifth year, the full complement of 110,000 drums is in storage.
- After the Test Phase, no more than 6000 drums (i.e., one full room) will be available as an underground emission source at a given time.
- No more than three TRUPACT-IIs (a total of 42 drums) will be opened in the WHB at any one time. Therefore, the maximum emission source aboveground is a 42-drum unit. It was assumed that three TRUPACT-IIs are always open in the WHB.
- Releases consist of vaporized organic solvents. The drums are sealed and vented through carbon filters. During Disposal Phase operations the integrity of the drums and their filters is maintained and, therefore, no particulates are available for release.

Table 5.29 gives the total emission periods used in conjunction with the air dispersion modeling to project potential concentrations at the human/environmental receptor locations.

Air Dispersion Modeling. As with radioactive waste contaminants, airborne release of hazardous chemicals from the WHB and the underground storage area constitute the most important potential exposure pathway. Exposures to workers in the facility and to the public receiving the maximum possible exposure (maximally exposed individual) due to inhalation of airborne releases were estimated. Consistent with radiological dose assessments (DOE, 1988c), the maximally-exposed member of the public is placed at the site boundary.

TABLE 5.29 Estimated emission period of volatile organics based on total concentrations and emission rates through the container filter

Chemical	Emission Period (Years)[a]		
	Minimum	Maximum	Weighted average
Carbon Tetrachloride	4	8,345	898
Methylene Chloride	3	37	23
Trichloroethylene	31	61,111	6,552
1,1,1-Trichlorethane	2	3280	352
1,1,2-Trichloro-1,2,2-Trifluoroethane	21	14,093	1,591

[a] The estimated total concentrations of each organic from Table 5.24 is multiplied by the emission rate given in Table 5.28 to determine the number of years that potential releases may occur assuming the gases flow at a constant rate through the carbon composite filter. An average drum weights 120 kg (WEC, 1989).

The EPA Industrial Source Complex (ISC) Dispersion Model predicts off-site concentrations of volatile organic gaseous releases from the WHB and underground storage areas. The same stack parameters (height, exhaust velocity, and diameter) were used in this model as in the AIRDOS-EPA radiological dispersion model (SEIS Appendix F). The long-term version of the model was used for routine operations, while the short-term version was used to predict off-site concentrations of chemicals during accident scenarios. A detailed description of these models and the input parameters is provided in Appendix G.

Risk Assessment and Characterization. The estimation of human health risks associated with potential exposures to hazardous chemicals conforms, where appropriate, to the guidance provided by the Superfund Public Health Evaluation Manual (SPHEM) (EPA, 1986). Consistent with the conservative approach, potential exposures to releases of hazardous chemicals resulting from Disposal Phase operations were estimated for hypothetical workers located at the points of maximum on-site concentrations above and below ground at points identified by the air dispersion modeling. Estimates of potential exposures were also made for a hypothetical residential receptor placed at the site boundary at a point of maximum potential exposure. The modeling results were used to assess air pathway exposures for these residential and occupational receptors. Short-term exposures were also evaluated for appropriate accidental release scenarios. A detailed description of the exposure parameters and calculations of risk estimations are given in Appendix G.

> Exposure Periods for Routine Operations. It was assumed that the residential exposure period is 24 hours per day, 365 days per year. This is a conservative assumption. The occupational exposure scenario was based on an eight-hour work day and a five-day work week. The working year was considered to be 240 days, allowing about 20 days per year for vacation, holidays, and sick leave.
>
> Exposure Periods for Accident Events. Accident scenarios were evaluated as short-term events. Times of occupational exposure were assumed for each scenario and exposure estimates were based on these times. For above ground accident events, it was assumed that a vapor cloud resulting from the accidental release would take one minute to pass the occupational worker location. For underground accidents, a 15-second period was assumed for the vapor cloud passage, although air flow is predicted in the FSAR to be 300 cm/sec. No particulate release is expected during these periods due to the nature of the waste form (SEIS, Appendix B). No data were available to estimate the probable duration of an underground fire in a single drum. A release period of 30 minutes was assumed for this hypothetical accident scenario.

Hazardous Chemical Risk Evaluation for Waste Retrieval. Risk evaluation for waste retrieval was calculated in the same way as for emplacement. Containers were assumed to maintain their integrity during the Test Phase and throughout the retrieval period.

5.2.4.2 Routine Releases and Exposures for Hazardous Chemicals. Routine releases of hazardous chemical constituents in the TRU waste are quantified in this section. Exposures to workers and the maximally-exposed member of the public who resides nearest the WIPP are discussed, and possible public health consequences are evaluated. Releases and exposures are predicted for the WIPP operations and waste retrieval.

Occupational Exposures from Aboveground Operations. Releases to the air are expected to occur during waste receipt, handling, and emplacement activities. Releases from TRU waste containers into the TRUPACT-II during transport may occur. Before opening the TRUPACT-II, samples will be taken from the sample port to detect any accumulation of hazardous chemicals. If hazardous chemicals are present, the TRUPACT-II will be opened under a negative air flow or purged, and hazardous volatile organic compounds will be removed by a charcoal filter system prior to release from the WHB. After receipt, individual drums being readied for emplacement in the underground storage chambers may be held in the WHB for a period of hours. Routine releases in the WHB are negligible, since diffusion rates of volatile organic compounds through filters are very low.

Consistent with the conservative approach for this assessment, a hypothetical worker was placed at the maximum concentration point for the above ground operations as predicted by the air dispersion modeling of the waste handling activities. Potential exposures to workers from above ground operations are postulated by assuming the presence of 42 drums (one TRUPACT-II truckload) in the WHB at all times, therefore, the daily intakes are the same for the Test Phase and operational period. The maximum concentration point from aboveground operations was 500 m south and 200 m west of the ventilation exhaust for the WHB, the assumed release point.

Table 5.30 gives the estimated concentrations in air of hazardous chemicals for the above ground occupational receptor location. These concentrations range from 2.4×10^{-7} $\mu g/m^3$ for trichloroethylene to 4.5×10^{-6} $\mu g/m^3$ for 1,1,1-trichloroethane. Table 5.30 also includes the estimated daily intakes for each chemical for the aboveground worker. The range of intakes is bounded by a low of 4.1×10^{-11} mg/kg-day for trichloroethylene and a high of 7.7×10^{-10} mg/kg-day for 1,1,1-trichloroethane.

Occupational Exposures from Underground Operations. Potential exposures to workers from underground operations may result from the off-gassing from drums placed in the underground storage rooms. To provide estimates of these potential exposures, hypothetical workers were placed:

- Underground in a storage chamber for an entire eight-hour shift each work day. This worker was assumed to be exposed to the emissions of a 6,000-drum unit. The exposure was based on a room volume of 3,600 m^3 and on air velocity of 3 m/sec.

TABLE 5.30 Occupational exposures and estimated daily intakes during aboveground operations

		Estimated daily intake[a] (mg/kg/day)			
		Minimum		Maximum	
Chemical	Concentration at receptor ($\mu g/m^3$)	5 years	20 years	5 years	20 years
Carbon Tetrachloride	5.9×10^{-7}	1.0×10^{-10}	1.0×10^{-10}	1.0×10^{-10}	1.0×10^{-10}
Methylene Chloride	2.0×10^{-6}	3.4×10^{-10}	3.4×10^{-10}	3.4×10^{-10}	3.4×10^{-10}
Trichloroethylene	2.4×10^{-7}	4.1×10^{-11}	4.1×10^{-11}	4.1×10^{-11}	4.1×10^{-11}
1,1,1-Trichloroethane	4.5×10^{-6}	7.7×10^{-10}	7.7×10^{-10}	7.7×10^{-10}	7.7×10^{-10}
1,1,2-Trichloro-1,2,2-Trifluoroethane	3.5×10^{-7}	6.0×10^{-11}	6.0×10^{-11}	6.0×10^{-11}	6.0×10^{-11}

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[a] Estimated daily intake (mg/kg/day) = [receptor concentration ($\mu g/m^3$)] $\frac{[1\ \text{mg}]}{[1000\ \mu g]}$ [respiratory volume (m^3/day)]/[body weight].

- Above ground at the maximum on-site concentration point as predicted by the air dispersion modeling of the underground releases. This point for releases resulting from underground operations is located 300 m south and 100 m west of the release point. This worker was also assumed to remain at that location for the duration of the eight-hour shift.

These exposure models are conservative since airflow in the waste chambers will place workers upstream of the waste storage room (DOE, 1988a). Table 5.31 gives the estimated concentrations in air of hazardous chemicals for both worker locations. These concentrations are based on the specific "drum units" for each scenario. Since 6,000 is the maximum number of drums in a room that an underground worker may be exposed to, the exposures are equal for both five and 20 year periods. However, an above ground worker may be exposed to a total of 110,000 drums during the Test Phase because no rooms will be backfilled during this time. The concentrations in the underground storage room range from 0.46 $\mu g/m^3$ for trichloroethylene to 8.6 $\mu g/m^3$ for 1,1,1-trichloroethane. At the above ground receptor location, concentrations during the five-year period range from 3.2×10^{-4} $\mu g/m^3$ for trichloroethylene to 6.0×10^{-3} $\mu g/m^3$ for 1,1,1-trichloroethane. During the 20-year period, concentrations at the above ground receptor location range from 8.7×10^{-5} $\mu g/m^3$ for trichloroethylene to 1.6×10^{-3} $\mu g/m^3$ for 1,1,1-trichloroethane.

The estimated daily intakes for each chemical for both receptor locations are included in Table 5.32. Estimates of daily intake for the underground receptor range from 7.9×10^{-5} mg/kg-day for trichloroethylene to 1.5×10^{-3} mg/kg-day for 1,1,1-trichloroethane. The range of intakes for the above ground worker during the 5-year period is 1.6×10^{-7} mg/kg-day for trichloroethylene to 3.1×10^{-6} mg/kg-day for 1,1,1-trichloroethane. During the 20 years of operations the intakes for the above ground worker are approximately an order-of-magnitude lower for each chemical constituent.

Residential Exposures from Aboveground Operations. Potential exposures to residential populations in the vicinity of the WIPP site may occur as a result of releases from the WHB during routine operations. Estimates of these potential exposures were calculated based on predicted maximum ground-level concentrations at the site boundary.

Table 5.33 gives the estimated concentrations in air of hazardous chemicals resulting from above ground operations for the hypothetical residential receptor located at the site boundary. These concentrations range from 5.0×10^{-8} $\mu g/m^3$ for trichloroethylene to 9.3×10^{-7} $\mu g/m^3$ for 1,1,1-trichloroethane. Table 5.33 also includes the estimated daily intakes for each chemical for this receptor location. The range of intakes is 1.4×10^{-11} mg/kg-day for trichloroethylene to 2.7×10^{-10} mg/kg-day for 1,1,1-trichloroethane. Again, no differences in exposure exist between the Test Phase and the 20-year Disposal Phase because the source term is a constant 42 drums in the WHB.

Residential Exposures from Underground Operations. Potential exposures to nearby residential populations may also occur as a result of releases from underground waste storage during routine operations. Estimates of these potential exposures are calculated based on predicted maximum ground-level concentrations at the site boundary.

TABLE 5.31 Occupational exposures from underground operations

	Concentration at receptor location			
	Underground worker (μg/m^3)		Aboveground worker (μg/m^3)	
Chemical	5 years	20 years	5 years	20 years
Carbon Tetrachloride	1.1	1.1	8.0×10^{-4}	2.1×10^{-4}
Methylene Chloride	3.8	3.8	2.7×10^{-3}	7.2×10^{-4}
Trichloroethylene	4.6×10^{-1}	4.6×10^{-1}	3.2×10^{-4}	8.7×10^{-5}
1,1,1-Trichloroethane	8.6	8.6	6.0×10^{-3}	1.6×10^{-3}
1,1,2-Trichloro-1,2,2-Trifluoroethane	6.7×10^{-1}	6.7×10^{-1}	4.6×10^{-4}	1.3×10^{-4}

TABLE 5.32 Routine estimated daily intakes for underground operations

	Estimated daily intakes at receptor location[a] (mg/kg/day)			
	Minimum		Maximum	
Chemical	5 years	20 years	5 years	20 years
I. Underground worker				
Carbon Tetrachloride	1.9×10^{-4}	1.9×10^{-4}	1.9×10^{-4}	1.9×10^{-4}
Methylene Chloride	6.6×10^{-4}	6.6×10^{-4}	6.6×10^{-4}	6.6×10^{-4}
Trichloroethylene	7.9×10^{-5}	7.9×10^{-5}	7.9×10^{-5}	7.9×10^{-5}
1,1,1-Trichloroethane	1.5×10^{-3}	1.5×10^{-3}	1.5×10^{-3}	1.5×10^{-3}
1,1,2-Trichloro-1,2,2-Trifluoroethane	1.2×10^{-4}	1.2×10^{-4}	1.2×10^{-4}	1.2×10^{-4}
I. Aboveground worker				
Carbon Tetrachloride	3.8×10^{-7}	3.6×10^{-8}	4.0×10^{-7}	3.6×10^{-8}
Methylene Chloride	9.4×10^{-7}	1.2×10^{-7}	1.4×10^{-6}	1.2×10^{-7}
Trichloroethylene	1.6×10^{-7}	1.5×10^{-8}	1.6×10^{-7}	1.5×10^{-8}
1,1,1-Trichloroethane	1.5×10^{-6}	2.8×10^{-7}	3.1×10^{-6}	2.8×10^{-7}
1,1,2-Trichloro-1,2,2-Trifluoroethane	2.4×10^{-7}	2.2×10^{-8}	2.4×10^{-7}	2.2×10^{-8}

[a] Estimated daily intake (mg/kg/day) = [receptor concentration ($\mu g/m^3$)] $\frac{[1\ mg]}{[1000\ \mu g]}$ [respiratory volume (m^3/day)]/[body weight].

TABLE 5.33 Residential exposures and estimated daily intakes during aboveground operations

Chemical	Concentration at the hypothetical residential receptor[a] ($\mu g/m^3$)	Estimated daily intake[b] (mg/kg/day) Minimum 5 years	Minimum 20 years	Maximum 5 years	Maximum 20 years
Carbon Tetrachloride	1.2×10^{-7}	3.5×10^{-11}	3.5×10^{-11}	3.5×10^{-11}	3.5×10^{-11}
Methylene Chloride	4.1×10^{-7}	1.2×10^{-10}	1.2×10^{-10}	1.2×10^{-10}	1.2×10^{-10}
Trichloroethylene	5.0×10^{-8}	1.4×10^{-11}	1.4×10^{-11}	1.4×10^{-11}	1.4×10^{-11}
1,1,1-Trichloroethane	9.3×10^{-7}	2.7×10^{-10}	2.7×10^{-10}	2.7×10^{-10}	2.7×10^{-10}
1,1,2-Trichloro-1,2,2-Trifluoroethane	7.2×10^{-8}	2.1×10^{-11}	2.1×10^{-11}	2.1×10^{-11}	2.1×10^{-11}

[a] Hypothetical residential receptor is located at the point of maximum air concentration at the WIPP site boundary.

[b] Estimated daily intake (mg/kg/day) = [receptor concentration ($\mu g/m^3$)] $\frac{[1\ mg]}{[1000\ \mu g]}$ [respiratory volume (m^3/day)]/[body weight].

Table 5.34 gives the estimated concentrations in air of hazardous chemicals resulting from underground operations for the hypothetical residential receptor located at the site boundary. Concentrations during the Test Phase ranged from 3.6×10^{-5} $\mu g/m^3$ for trichloroethylene to 6.6×10^{-4} $\mu g/m^3$ for 1,1,1-trichloroethane. The air concentrations during the Disposal Phase are somewhat lower with a range from 9.7×10^{-6} for trichloroethylene to 1.8×10^{-4} for 1,1,1-trichloroethane. The estimated daily intakes for each chemical for the residential receptor location are also included in Table 5.34. The range of intakes during the Test Phase is 3.1×10^{-8} mg/kg-day for trichloroethylene to 5.7×10^{-7} mg/kg-day for 1,1,1-trichloroethane. The exposures to hazardous chemicals during the operational phase are approximately an order-of-magnitude lower in all cases.

Waste Retrieval Releases and Exposures. If retrieval should become necessary, air samples would be taken in waste storage areas prior to entry to confirm that air concentrations of hazardous chemicals are within health-based limits. Appropriate respiratory protection would be worn if needed.

The routine releases of hazardous chemicals during waste retrieval are expected to be identical to releases during emplacement. The integrity of the waste containers are not expected to deform or degrade during the retrievable storage period. The WAC requires that waste containers meet all requirements of 49 CFR Part 173.412 for Type A packaging, including a design life of at least 20 years.

Exposures during routine retrieval operations were predicated on the assumptions established for routine waste emplacement. Workers involved with retrieval activities were assumed to be subject to the same exposure as those involved in underground emplacement activities during the first few years of facility operations. The annual average hazardous chemical exposure to the maximally-exposed member of the public would be no greater than that estimated for the first few years of underground emplacement activities.

5.2.4.3 Accidental Releases and Exposures for Hazardous Chemicals. The accident scenarios for hazardous chemical releases and exposures are identical to those described for accidental radiological releases in Appendix F. They are identified by the same letter codes.

In modeling chemical releases, it was assumed that the total release of volatile organics equals the calculated void volume gas concentration for a given chemical (Subsection 5.2.4.1). Releases and potential acute exposures were estimated for occupational receptors in the immediate vicinity of the accident. Table 5.35 includes the estimated release fractions and potential exposures to these chemicals.

Occupational Exposures from Above ground Accidents. There are two hypothetical accident scenarios that are applicable to above ground operations. These accidents are postulated to occur in the WHB.

TABLE 5.34 Residential exposures and estimated daily intakes during underground operations

Chemical	Concentration at the hypothetical residential receptor		Estimated daily intake[a] (mg/kg/day)			
			Minimum		Maximum	
	5 years	20 years	5 years	20 years	5 years	20 years
Carbon Tetrachloride	8.7×10^{-5}	2.4×10^{-5}	7.0×10^{-8}	6.8×10^{-9}	7.4×10^{-8}	6.8×10^{-9}
Methylene Chloride	3.0×10^{-4}	8.1×10^{-5}	1.8×10^{-7}	2.3×10^{-8}	2.5×10^{-7}	2.3×10^{-8}
Trichloroethylene	3.6×10^{-5}	9.7×10^{-6}	3.1×10^{-8}	2.8×10^{-9}	3.1×10^{-8}	2.8×10^{-9}
1,1,1-Trichloroethane	6.6×10^{-4}	1.8×10^{-4}	2.9×10^{-7}	5.2×10^{-8}	5.7×10^{-7}	5.2×10^{-8}
1,1,2-Trichloro-1,2,2-Trifluoroethane	5.1×10^{-5}	1.4×10^{-5}	4.4×10^{-8}	4.0×10^{-9}	4.4×10^{-8}	4.0×10^{-9}

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[a] Estimated daily intake (mg/kg/day) = [receptor concentration (μg/m³)] $\frac{[1\ \text{mg}]}{[1000\ \mu\text{g}]}$ [respiratory volume (m³/day)]/[body weight].

TABLE 5.35 Releases, worker exposures, and estimated intakes from projected accidents during WIPP facility operations

Accident[c]	Chemical	Release (g)	Concentration at Receptor[a] (mg/m^3)	Estimated Intake[b] (mg/exposure)
C2	CCl_4	2.7×10^{-1}	5.8×10^{-1}	1.4×10^{-2}
	MeCl	6.9×10^{-2}	1.5×10^{-1}	3.7×10^{-3}
	TCA	1.9×10^{0}	4.1×10^{0}	1.0×10^{-1}
	Freon	1.8×10^{-1}	3.8×10^{-1}	9.5×10^{-3}
	TCE	1.0×10^{-1}	2.2×10^{-1}	5.4×10^{-3}
C3	CCl_4	8.2×10^{-1}	1.7×10^{0}	4.3×10^{-2}
	MeCl	2.1×10^{-1}	4.4×10^{-1}	1.1×10^{-2}
	TCA	5.8×10^{0}	$1.2 \times 10^{+1}$	3.1×10^{-1}
	Freon	5.4×10^{-1}	1.1×10^{0}	2.9×10^{-2}
	TCE	3.1×10^{-1}	6.5×10^{-1}	1.6×10^{-2}
C4/C5	CCl_4	2.7×10^{-1}	3.3×10^{0}	2.1×10^{-2}
	MeCl	6.9×10^{-2}	8.3×10^{-1}	5.2×10^{-3}
	TCA	1.9×10^{0}	$2.3 \times 10^{+1}$	1.5×10^{-1}
	Freon	1.8×10^{-1}	2.2×10^{0}	1.4×10^{-2}
	TCE	1.0×10^{-1}	1.2×10^{0}	7.8×10^{-3}
C6	CCl_4	8.2×10^{-1}	9.8×10^{0}	6.2×10^{-2}
	MeCl	2.1×10^{-1}	2.5×10^{0}	1.6×10^{-2}
	TCA	5.8×10^{0}	$7.0 \times 10^{+1}$	4.4×10^{-1}
	Freon	5.4×10^{-1}	6.5×10^{0}	4.1×10^{-2}
	TCE	3.1×10^{-1}	3.7×10^{0}	2.3×10^{-2}
C10	CCl_4	2.7×10^{-1}	3.3×10^{0}	2.1×10^{-2}
	MeCl	6.9×10^{-2}	8.3×10^{-1}	5.2×10^{-3}
	TCA	1.9×10^{0}	$2.3 \times 10^{+1}$	1.5×10^{-1}
	Freon	1.8×10^{-1}	2.2×10^{0}	1.4×10^{-2}
	TCE	1.0×10^{-1}	1.2×10^{0}	7.8×10^{-3}
	Lead	2.7×10^{-7}	5.5×10^{-6}	2.1×10^{-5}

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[a] Modeled as a hemispheric cloud expanding at a rate equivalent to the ventilation flow rate in the accident area. Receptor concentration specific to each accident scenario (Appendix G).

[b] Estimated intakes are based on the formula: Intake = Receptor Conc. x Respiratory Volume x Exposure Period. The transfer coefficient is assumed to be 1.00 for all chemicals. Respiratory volume is assumed to be 12 m^3/work day and the exposure periods are given in Appendix G.

[c] A detailed description of the accident scenarios is given in Appendix F.

Accident ID C2. A single drum is dropped from a forklift. Concentrations of hazardous chemicals at a worker 20 feet away range from 1.5×10^{-1} mg/m^3 for methylene chloride to 4.1 mg/m^3 for 1,1,1-trichloroethane. The estimated intake range resulting from a one-minute exposure is 3.7×10^{-3} mg for methylene chloride to 1.0×10^{-1} mg for 1,1,1-trichloroethane.

Accident ID C3. Two drums are punctured by a forklift. A third drum falls and ruptures as a result of the initial accident. Concentrations at a worker 20 feet away range from 4.4×10^{-1} mg/m^3 for methylene chloride to 1.2×10^{1} mg/m^3 for 1,1,1-trichloroethane. The estimated intake range resulting from a one-minute exposure is 1.1×10^{-2} mg for methylene chloride to 3.1×10^{-1} mg for 1,1,1-trichloroethane.

Occupational Exposures from Underground Accidents. There are four hypothetical accident scenarios that are applicable to underground operations. These accidents were postulated to occur in underground storage areas.

Accident ID C4. A transporter hits a pallet of drums in the underground storage area. As a result, the lid is knocked off of one drum. Concentrations at a worker in the vicinity range from 8.3×10^{-1} mg/m^3 for methylene chloride to 2.3×10^{1} mg/m^3 for 1,1,1-trichloroethane. The estimated intake range resulting from a 15-second exposure is 5.2×10^{-3} mg for methylene chloride to 1.5×10^{-1} mg for 1,1,1-trichloroethane.

Accident ID C5. A single drum is dropped from a forklift. Due to the head-space gas release assumption, this is an identical scenario to C4. The concentration and intake ranges remain the same.

Accident ID C6. Two drums are punctured by a forklift. A third drum falls and ruptures as a result of the initial accident. Concentrations at a worker in the vicinity range from 2.5 mg/m^3 for methylene chloride to 7.0×10^{1} mg/m^3 for 1,1,1-trichloroethane. The estimated intake range resulting from a 15-second exposure is 4.6×10^{-2} mg for methylene chloride to 4.4×10^{-1} mg for 1,1,1-trichloroethane.

Accident ID C10. A spontaneous ignition event occurs in a single drum in an underground storage chamber. To estimate exposures from this incident, it was assumed that all gasses in the void volume of the drums were released instantaneously at ignition. The releases and exposures from this event were found to be identical to those for C4 and C5.

Estimations of particulate releases of lead have been made based on the vapor pressure of elemental lead. A receptor concentration and intake were estimated for an above ground receptor at the point of maximum concentration as predicted by short-term air dispersion modeling for underground releases. Exposure to an underground worker to volatile organics and lead is not considered as a reasonably foreseeable event because of the duration of the event and the location of workers during the accident (Appendix F).

The release period was assumed to last for 30 minutes. Lead volatilization was estimated for a temperature of 1300°K (1027°C). Of the potentially vaporized lead, 0.25 percent was assumed to be released as an aerosol. As the heated aerosol encounters the cool bedded salt surface, a high deposition rate was predicted. This removal rate was assumed to be 80 percent. No credit was taken for HEPA filtration of the exhaust for the underground storage area. These assumptions are consistent with the accident scenario for radiological exposures.

Using these assumptions in conjunction with the air dispersion modeling data produced an estimated above ground receptor concentration of 5.5×10^{-6} mg/m^3 of free lead. The estimated intake resulting from 30 minutes exposure at this concentration is 2.1×10^{-5} mg.

5.2.4.4 Human Health and Environmental Consequences of Hazardous Chemical Releases. Estimated releases of and consequent exposures to potentially hazardous chemicals in TRU wastes are related to potential risks to human health and the environment. In this assessment, risks to human health are expressed as incremental risk of excess cancers for carcinogenic chemical exposures. Exposures to noncarcinogenic chemicals are compared to established health-protective levels for noncarcinogenic exposures.

Estimation of Potential Risks from Routine Exposure to Carcinogens. Table 5.36 gives R_i values (incremental lifetime cancer risks) for the three carcinogens evaluated. For residential exposures, carbon tetrachloride has a total estimated excess cancer risk range (i.e., the sum of above ground and underground routine operations) of 6.5×10^{-10} to 6.9×10^{-10} over the five-year Test Phase or slightly more than one excess case in a population of four billion. The total estimated excess cancer risk range associated with potential residential exposures to methylene chloride during these five years at the WIPP site was 9.4×10^{-11} to 1.4×10^{-10}, or at most slightly more than one case in twenty billion population. Similarly, the maximum total estimated cancer risk associated with trichloroethylene was 2.8×10^{-11} during this period. The estimated excess cancer risk associated with these chemicals during the 20-year operational program was within these same ranges, indicating no greater risk to the public during WIPP operations.

For occupational aboveground exposures at the WIPP facility during the Test Phase, the excess total cancer risk range for carbon tetrachloride was estimated to be 7.7×10^{-10} to 8.2×10^{-10} (Table 5.36). Methylene chloride has a total estimated excess cancer risk range of 1.1×10^{-10} to 1.6×10^{-10} (Table 5.36). The maximum excess cancer risk associated with trichloroethylene during this period was estimated to be 3.3×10^{-11}. Again, the risk associated with 20 years of operations was in a similar range.

For occupational underground exposures, the excess total cancer risk from carbon tetrachloride is estimated to be 3.9×10^{-7} (Table 5.36). Methylene chloride has a total estimated excess cancer risk of 7.7×10^{-8} or at most nearly three orders of magnitude less than the 10^{-4} level. Trichloroethylene has a maximum total estimated cancer risk of 1.6×10^{-8} for this period.

TABLE 5.36 Incremental lifetime cancer risks for routine releases[a]

	Receptors											
	Residential				Aboveground occupational				Underground occupational			
	Minimum		Maximum		Minimum		Maximum		Minimum		Maximum	
	5 years	20 years	5 years	20 years	5 years	20 years	5 years	20 years	5 years	20 years	5 years	20 years
I. Aboveground Operations												
Carbon Tetrachloride	$3.2x10^{-13}$	$1.3x10^{-12}$	$3.2x10^{-13}$	$1.3x10^{-12}$	$2.1x10^{-13}$	$8.2x10^{-13}$	$2.1x10^{-13}$	$8.2x10^{-13}$	NA	NA	NA	NA
Methylene Chloride	$6.3x10^{-14}$	$2.5x10^{-13}$	$6.3x10^{-14}$	$2.5x10^{-13}$	$4.0x10^{-14}$	$1.6x10^{-13}$	$4.0x10^{-14}$	$1.6x10^{-13}$	NA	NA	NA	NA
Trichloroethylene	$1.3x10^{-14}$	$5.3x10^{-14}$	$1.3x10^{-14}$	$5.3x10^{-14}$	$8.4x10^{-15}$	$3.4x10^{-14}$	$8.4x10^{-15}$	$3.4x10^{-14}$	NA	NA	NA	NA
II. Underground Operations												
Carbon Tertrachloride	$6.5x10^{-10}$	$2.5x10^{-10}$	$6.9x10^{-10}$	$2.5x10^{-10}$	$7.7x10^{-10}$	$3.0x10^{-10}$	$8.2x10^{-10}$	$3.0x10^{-10}$	$3.9x10^{-7}$	$1.6x10^{-6}$	$3.9x10^{-7}$	$1.6x10^{-6}$
Methylene Chloride	$9.4x10^{-11}$	$4.9x10^{-11}$	$1.4x10^{-10}$	$4.9x10^{-11}$	$1.1x10^{-10}$	$5.8x10^{-11}$	$1.6x10^{-10}$	$5.8x10^{-11}$	$7.7x10^{-8}$	$3.1x10^{-7}$	$7.7x10^{-8}$	$3.1x10^{-7}$
Trichloroethylene	$2.8x10^{-11}$	$1.0x10^{-11}$	$2.8x10^{-11}$	$1.0x10^{-11}$	$3.3x10^{-11}$	$1.2x10^{-11}$	$3.3x10^{-11}$	$1.2x10^{-11}$	$1.6x10^{-8}$	$6.5x10^{-8}$	$1.6x10^{-8}$	$6.5x10^{-8}$

NA = Not applicable

For comparison, the baseline cancer incidence in the United States is about 3 in 10, about 80 percent of which result in death attributable to the disease (American Cancer Society, 1988).

Estimation of Potential Risks from Routine Exposure to Noncarcinogens. The data base compiled from the Rocky Flats Plant and the Idaho National Engineering Laboratory waste profiles yielded two volatile organic noncarcinogens present in quantities of greater than one percent by weight. Risks associated with noncarcinogens are presented in terms of hazard indices (Appendix G). The estimated daily intakes of the various receptors given in Tables 5.32 to 5.34 are divided by the acceptable reference levels in this case Acceptable Intake; Chronic (AICs), (EPA, 1986). Hazard indices (HI) of less than unity indicate levels of exposure below the AIC. Because of the low concentrations of these chemicals, no differences in hazard indices were detectedfor residential receptors or aboveground workers between the Test Phase and the operational period from aboveground operations. The HI for 1,1,1-trichloroethane was 4.2×10^{-11} for residential exposures during aboveground operations (Table 5.37), and 1.2×10^{-10} for aboveground occupational exposures. The residential HI for 1,1,2-trichloro-1,2,2-trifluoroethane was 6.8×10^{-13}, while the HI for the aboveground worker was 2.0×10^{-12}. The chemical-specific HIs are, in every case, considerably less than unity.

The hazard indices for 1,1,1-trichloroethane exposures to the public and both above and below ground workers are slightly higher from underground operations, although all calculated hazard indices are well below unity. The highest hazard index was 2.3×10^{-4} for 1,1,1-trichloroethane, associated with the hypothetical and unrealistic scenario of a worker remaining in a room with 6000 drums for 8 hours.

Estimation of Potential Risks from On-Site Accident Events. On-site accident scenarios all represent acute (i.e., exceedingly short-term) exposures. Both chemical-specific Threshold Limit Values (TLVs) (ACGIH, 1986) and Immediate Danger to Life and Health (IDLH) criteria (CHEMTOX, 1988) were used as reference levels in calculating accident-related HIs. The exception to this is lead for which there is no IDLH. Tables 5.38 and 5.39 includes risks associated with the release of hazardous chemicals from on-site accidents at the WIPP.

Occupational Risks from Aboveground Accidents. There are two hypothetical accident scenarios that are applicable to above ground operations. Both of these accidents were postulated to occur in the WHB. Predicted exposures from these accidents are reviewed in Subsection 5.2.4.3. Detailed exposure estimates are given in Table 5.35.

Accident ID C2. A single drum is dropped from a forklift. The IDLH-based HIs range from 2.8×10^{-7} for methylene chloride to 2.5×10^{-5} for 1,1,1-trichloroethane (Table 5.38). The TLV-based HIs range from 1.0×10^{-7} for Freon to 4.0×10^{-5} for carbon tetrachloride (Table 5.39).

TABLE 5.37 Hazard indices for routine releases[a]

	Receptors											
	Residential				Aboveground occupational				Underground Occupational			
	Minimum		Maximum		Minimum		Maximum		Minimum		Maximum	
	5 years	20 years	5 years	20 years	5 years	20 years	5 years	20 years	5 years	20 years	5 years	20 years
I. Aboveground operations												
1,1,1-Trichloroethane	4.2×10^{-11}	4.2×10^{-11}	4.2×10^{-11}	4.2×10^{-11}	1.2×10^{-10}	1.2×10^{-10}	1.2×10^{-10}	1.2×10^{-10}	NA	NA	NA	NA
1,1,2- Trichloro-1,2,2-Trifluoroethane	6.8×10^{-13}	6.8×10^{-13}	6.8×10^{-13}	6.8×10^{-13}	2.0×10^{-12}	2.0×10^{-12}	2.0×10^{-12}	2.0×10^{-12}	NA	NA	NA	NA
II. Underground operations												
1,1,1-Trichloroethane	4.6×10^{-8}	8.2×10^{-9}	9.0×10^{-8}	8.2×10^{-9}	2.5×10^{-7}	4.4×10^{-8}	4.9×10^{-7}	4.4×10^{-8}	2.3×10^{-4}	2.3×10^{-4}	2.3×10^{-4}	2.3×10^{-4}
1,1,2-Trichloro-1,2,2-Trifluoroethane	1.5×10^{-9}	1.3×10^{-10}	1.5×10^{-9}	1.3×10^{-10}	7.9×10^{-9}	7.2×10^{-10}	7.9×10^{-9}	7.2×10^{-10}	3.8×10^{-6}	3.8×10^{-6}	3.8×10^{-6}	3.8×10^{-6}

NA = Not applicable

[a] Hazard Index = Estimated daily intake/AIC.

TABLE 5.38 IDLH-based hazard indices (HIs) for accidents during routine operations

Accident[d]	Chemical	IDLH[a] (mg/m^3)	IDLH-Based Allowable Intake[b] (mg/exposure)	IDLH-Based HIs[c]
C2	CCl_4	1,800	1,350	1.1×10^{-5}
	MeCl	17,500	13,125	2.8×10^{-7}
	TCA	5,429	4,071	2.5×10^{-5}
	TCE	5,400	4,050	1.3×10^{-6}
	Freon	34,200	25,650	3.7×10^{-7}
C3	CCl_4	1,800	1,350	3.2×10^{-5}
	MeCl	17,500	13,125	8.4×10^{-7}
	TCA	5,429	4,071	7.6×10^{-5}
	TCE	5,400	4,050	4.0×10^{-6}
	Freon	34,200	25,650	1.1×10^{-6}
C4/C5	CCl_4	1,800	1,350	1.5×10^{-5}
	MeCl	17,500	13,125	4.0×10^{-7}
	TCA	5,429	4,071	3.6×10^{-5}
	TCE	5,400	4,050	1.9×10^{-6}
	Freon	34,200	25,650	5.3×10^{-7}
C6	CCl_4	1,800	1,350	4.6×10^{-5}
	MeCl	17,500	13,125	1.2×10^{-6}
	TCA	5,429	4,071	1.1×10^{-4}
	TCE	5,400	4,050	5.7×10^{-6}
	Freon	34,200	25,650	1.6×10^{-6}
C10	CCl_4	1,800	1,350	1.5×10^{-5}
	MeCl	17,500	13,125	4.0×10^{-7}
	TCA	5,429	4,071	3.6×10^{-5}
	TCE	5,400	4,050	1.9×10^{-6}
	Freon	34,200	25,650	5.3×10^{-7}
	Pb	NA	NA	NA

[a] CHEMTOX Data Base, 1988.

[b] The IDLH is the maximum concentration in air from which one could escape within 30 minutes without any escape-impairing symptoms or irreversible health effects (Sittig, 1985). Therefore, the IDLH-based allowable intake uses the formula in Appendix G above with an exposure period of 30 minutes or 1/16th of the workday.

[c] IDLH-based hazard index = Estimated Intake/IDLH-Based Allowable Intake.

[d] A detailed description of the accident scenarios is given in Appendix F.

TABLE 5.39 TLV-based hazard indices (HIs)

Accident[a]	Chemical	TLV-TWA[b] (mg/m^3)	TLV-Based Estimated Intake[c] (mg/exposure)	TLV-Based HIs[d]
C2	CCl_4	30	360	4.0×10^{-5}
	MeCl	175	2,100	1.7×10^{-6}
	TCA	1,900	22,800	4.5×10^{-6}
	TCE	270	3,240	1.7×10^{-6}
	Freon	7,600	91,200	1.0×10^{-7}
C3	CCl_4	30	360	1.2×10^{-4}
	MeCl	175	2,100	5.2×10^{-6}
	TCA	1,900	22,800	1.4×10^{-5}
	TCE	270	3,240	5.0×10^{-6}
	Freon	7,600	91,200	3.1×10^{-7}
C4/C5	CCl_4	30	360	5.7×10^{-5}
	MeCl	175	2,100	2.5×10^{-6}
	TCA	1,900	22,800	6.4×10^{-6}
	TCE	270	3,240	2.4×10^{-6}
	Freon	7,600	91,200	1.5×10^{-7}
C6	CCl_4	30	360	1.7×10^{-4}
	MeCl	175	2,100	7.4×10^{-6}
	TCA	1,900	22,800	1.9×10^{-5}
	TCE	270	3,240	7.2×10^{-6}
	Freon	7,600	91,200	4.5×10^{-7}
C10	CCl_4	30	360	5.7×10^{-5}
	MeCl	175	2,100	2.5×10^{-6}
	TCA	1,900	22,800	6.4×10^{-6}
	TCE	270	3,240	2.4×10^{-6}
	Freon	7,600	91,200	1.5×10^{-7}
	Pb	0.15	9	2.3×10^{-6}

[a] A detailed description of the accident scenarios is given in Appendix F.

[b] ACGIH, 1986.

[c] The TLV is a time-weighted average for an 8-hour period intended to protect workers over a career of exposure. Therefore, the TLV-based estimated intake uses the formula in Appendix G with an exposure period of 8 hours.

[d] TLV-based hazard index is = Estimated Intake/TLV-Based Allowable Intake.

Accident ID C3. Two drums are punctured by a forklift. A third drum falls and ruptures as a result of the initial accident. The IDLH-based HIs range from 8.4×10^{-7} for methylene chloride to 7.6×10^{-5} for 1,1,1-trichloroethane (Table 5.38). The TLV-based HIs range from 3.1×10^{-7} for Freon to 1.2×10^{-4} for carbon tetrachloride (Table 5.39).

Occupational Risks from Underground Accidents. There are four hypothetical accident scenarios that are applicable to underground operations. All of these accidents were postulated to occur in underground storage areas. Risks associated with these accidents were also included in Tables 5.38 and 5.39.

Accident ID C4. A transporter hits a pallet of drums in the underground storage area. As a result, the lid is knocked off of one drum. The IDLH-based HIs range from 4.0×10^{-7} for methylene chloride to 3.6×10^{-5} for 1,1,1-trichloroethane. The TLV-based HIs range from 1.5×10^{-7} for Freon to 5.7×10^{-5} for carbon tetrachloride.

Accident ID C5. A single drum is dropped from a forklift. Due to the head space gas release assumption, this is an identical scenario to C4. The IDLH-based HI and TLV-based HI ranges remain the same.

Accident ID C6. Two drums are punctured by a forklift. A third drum falls and ruptures as a result of the initial accident. The IDLH-based HIs range from 1.2×10^{-6} for methylene chloride to 1.1×10^{-4} for 1,1,1-trichloroethane. The TLV-based HIs range from 4.5×10^{-7} for freon to 1.7×10^{-4} for carbon tetrachloride.

Accident ID C10. A spontaneous ignition event occurs in a single drum in an underground storage chamber. To estimate exposures from this incident, it was assumed that all of the gasses in the void volume of the drums would be released instantaneously at ignition. The IDLH-based HI and TLV-based HI ranges for this event were identical to those for C4 and C5 (Tables 5.38 and 5.39, respectively).

Estimations of particulate releases of lead were made based on the vapor pressure of elemental lead. A receptor concentration and intake were estimated for an aboveground receptor at the point of maximum concentration as predicted by short-term air dispersion modeling for underground releases. Using the assumptions given in Subsection 5.2.4.3, the TLV-based HI for lead is 2.3×10^{-6} (Table 5.39).

Residential Risks from On-Site Accident Events. The estimated HI ranges for occupational receptors in the near vicinity of each accident event are provided above. For each accident event, the maximum HI is at least three orders of magnitude less than unity. If hazardous chemicals were to be transported to the hypothetical receptor at the site boundary as a result of atmospheric dispersion of any of the on-site accident releases, the dilution in the vastly increased air volume (coupled with the increased diffusion) would produce expected HI ranges which had maximum values even less than the already very small HIs estimated for the on-site occupational receptor.

Consequences of Waste Retrieval. Hazardous chemical exposures from both routine and accidental releases during waste retrieval were predicted to be the same or less than exposures during waste emplacement. The associated human health consequences are in the same low range.

5.2.4.5 Uncertainty Analysis. Human health risks posed by a defined set of circumstances may be evaluated both qualitatively and quantitatively. The precision of these estimates is limited by the size and quality of the data base. In this assessment, these limitations have been mitigated by defining a range of extremes. However, there are varying degrees of uncertainty associated with estimating the risks that may result from chemical exposure. These uncertainties have been addressed throughout the risk assessment by making conservative assumptions where appropriate. Specific areas of uncertainty include the following:

- Receptor populations
- Waste characterization
- Air dispersion modeling
- Exposure estimates
- Toxicological data and risk characterization
- Complex interactions of uncertainty elements.

The uncertainty elements are reviewed here. Despite the conservative assumptions employed to counteract the uncertainties, the estimates of risk are best viewed in a qualitative sense, i.e., in relation to other potential risks and not as absolutes.

Receptor Populations. To achieve the most precise estimates of potential risks (if any) to the community, populations representing varied exposure scenarios should be modeled. Recognizing this variability, receptor locations were selected to include a hypothetical residential receptor located at the maximum predicted concentration point at the site boundary, a hypothetical worker located at the maximum on-site concentration point, and a hypothetical worker located in an underground storage chamber throughout his work shift.

In addition, the locations of potential maximum off-site ambient air concentrations of the representative chemicals were also subjected to air transport and exposure assessment modeling. The exposure scenario assumed that a hypothetical residential receptor would be continually exposed to the highest potential WIPP site boundary concentration of each type of chemical constituent. In fact, no individual can be expected to remain in the same location 24 hours per day, 365 days per year for 25 years. Similarly, no job description requires a worker to remain at a single location throughout his working lifetime. Therefore, this scenario does not reflect the present circumstances, nor any future projected exposure.

Waste Characterization. To derive a chemical-specific emissions data base, an evaluation of the limited data available concerning the potential future waste was performed. The waste that is expected to be accepted at the proposed facility is based on RCRA data for the waste stored at the Rocky Flats facility, process information, and a single study of headspace gas concentrations (Clements and Kudera, 1985). From these data, a list of six "representative" chemicals was selected. It must be stressed that although other constituents are expected to be present in the waste, quantitative analytical data do not exist for both waste composition and headspace gas concentration. The quality of the data suggests that it would be prudent to view the numerical results in a qualitative and, therefore, relative sense.

Air Dispersion Modeling. Meteorological dispersion was estimated using the ISC model in both short-term and long-term modes. Accuracy of the ISC model projections is generally recognized to be within a factor of two. For example, if the concentration calculated for a given receptor location is 100, then the actual concentration would be expected to fall in the range of 50 to 200 (i.e., 100/2 to 100x2).

Calculations for the long-term concentrations assumed a constant emission rate over an annual period. Short-term concentrations were calculated using generic meteorological data. The receptor concentrations reported for short-term events were the highest of those estimated from the 49 combinations of wind speed and direction.

Exposure Elements. The exposure assessment utilized mathematical models that relied heavily on estimates of the ultimate disposition of the representative chemicals and their transport through inhalation. A review of the basis for mathematical models for exposure estimation is provided below. Model assumptions are reviewed below to illustrate the conservative bias built into the assumptions to compensate for uncertainty. Where reasonable approximations of the site-specific scenario could be estimated, health-protective "default" values that erred on the side of overestimation of exposure were utilized. No field studies were performed. Existing data obtained from appropriate sources were employed.

Basis for the Mathematical Models of Exposure Assessment. Mathematical models, such as those employed in the exposure assessment, are helpful in providing numerical approximations of a biological system's response given a particular set of input conditions and constraints. The risk assessment models provide predictive estimates of the effects of chemicals in a given biological system. Here, the biological systems affected are the individual receptor populations.

Any attempt to model a biological system incorporates some degree of uncertainty. For example, in modeling the transfer of a chemical across the alveoli in the lung, it is necessary to quantify penetration to the deep lung and the absorption rate across alveolar membranes. If these values do not exist as a result of previous scientific inquiry, assumptions are made that permit estimation form the best available, most relevant information. The precision of the resulting estimate of dose incurred depends on the accuracy of these assumptions reflecting actual events.

In essence, the scientist has taken a system in which many variables exist and constructed a manageable model of that system by assuming those variables are constant at a defined level. This approach sets the input chemical concentration as the only independent variable in the model. A linear relationship is assumed that is not necessarily reflective of real-world conditions. The dependent variable (the intake) becomes a function of chemical concentration alone, which may not adequately represent site-specific conditions. This intake is qualified by the constraints on the model.

Assumptions Used in the Exposure Assessment. The assumptions used in the health-protective approach to defining the variables include the following:

- Continuous emissions from the WIPP (i.e., 24 hours a day, 365 days a year for the 5-year Test Phase and the 20-year facility operating life)
- One hundred percent uptake and absorption of volatile organics
- Continuous maximum exposures for residential receptors (i.e., 24 hours a day, 365 days a year for 25 years)
- Continuous maximum exposures for each occupation receptor for each shift.

Toxicological Data and Risk Characterization. The overriding uncertainties associated with the risk characterization are:

- The extrapolation of toxic or carcinogenic effects observed at the high doses necessary to conduct animal studies to effects that might occur at much lower, "real-world" doses
- The extrapolation from toxic effects in animals to toxic effects in people (i.e., responses of animals may be different from responses of humans).

These extrapolations form the basis for the derivation of the factors used to estimate risks. The carcinogenic potency factors (CPFs) are derived using a weight-of-evidence approach to studies in the scientific literature (EPA, 1986). Due to the lack of human epidemiological data for most chemicals, the evidence results from animal studies in which experimental groups were exposed for most of their lifetime to doses many times those normally found in the environment. In some cases, only a single study may be used in this derivation process.

The EPA uses a prescribed protocol (EPA, 1986) to evaluate animal data to estimate human cancer potency factors. The model utilized is the linearized multistage extrapolation model which provides a mathematical approximation of the dose-response slopes. Of the half dozen equally feasible dose-response extrapolation models available, the one selected by these agencies as applied here is designed to define the highest upper bound risk condition. The results from this model likely overestimate the actual risk rather than under-estimate it. The scientific evidence relating to the mechanism by which some of the chemicals in the data base (e.g. chlorinated hydrocarbons) induce cancer in rodents, leads to the conclusion that they may require additional biological alteration before initiating cancer. This renders those models invalid for application to those chemicals. In addition, because the slope estimates are based on animal data, the ratio of cancer potency slopes between chemicals may be more reflective of animal responses than human. In short, because the models do not incorporate the role of biologic protective mechanisms or human epidemiology, they are only gross indicators that are specifically designed to most likely overestimate potential risks.

Much valuable information has been gained from animal studies as a result. However, variations in pharmacokinetics and metabolism occur when identical experiments are carried out using different animal species. These species-to-species variations in responses exacerbate the already difficult task of extrapolating from effects seen in animal studies to predicting effects in humans. In addition, the metabolic or pharmacokinetic idiosyncrasies of a given animal model may result in effects that may not be observed in humans because humans may respond to a given chemical differently.

The high doses used in these animal studies also add additional levels of uncertainty. High dose levels may result in saturation effects in certain biochemical systems of an organism. For example, enzyme kinetics are vastly altered at substrate saturation levels. Effects seen at high doses may not be representative of the kinetics of the particular enzyme system under lower-dose, nonsaturated conditions.

Even in cases where there are adequate epidemiological data, uncertainty persists. The exposures in such studies are not controlled in the sense of a laboratory experiment, and it is often impossible to isolate an exposure to a specific chemical. Therefore, the effect(s) observed may actually result from the interaction of a mixture of chemicals peculiar to that exposure incident. Unless the potential chemical mixture is fully defined, extrapolation to other exposure scenarios cannot be made without uncertainty.

Acceptable intakes for chronic exposure, threshold limit values and ceiling limits that have been established for noncarcinogens are derived in a similar manner. Hence, the same degree of uncertainty exists.

Complex Interaction of Uncertainty Elements. A risk assessment of a site is ultimately an integrated evaluation of historical, chemical, analytical, environmental, demographic, and toxicological data that are as site-specific as possible. To minimize the effect of uncertainties in the evaluation, each step is biased toward health-protective estimations. Since each step builds on the previous one, this biased approach more than compensates for risk assessment uncertainties. In addition, these calculations do not represent currently existing or expected future exposures or health risks. Rather, they are estimations that may occur only if all of the conservative assumptions are realized.

5.3 SEIS ALTERNATIVE ACTION

This subsection discusses the potential environmental consequences associated with the Alternative Action.

5.3.1 Biology

Conducting the bin-scale tests at the Idaho National Engineering Laboratory (or other DOE facilities) would have very little impact on the general environment. The test facility would require less than 0.25 acre of land for construction. This small amount of land area would not significantly affect wildlife habitat at the 890 square mile (mi^2) Laboratory.

Impacts associated with operation of the WIPP after the bin-scale tests would be the same as for the Proposed Action (SEIS Subsection 5.1.1).

5.3.2 Socioeconomics

Facility construction and operation would not significantly affect the work force or communities surrounding the Idaho National Engineering Laboratory. Design and construction of the bin-scale test facility was assumed to occur over a two-year period. Construction costs were estimated to be about $3.5 million. A large work force would not be required and could easily be attained from the available surrounding work force. Approximately 3400 construction personnel are available within a 50-mile radius of the Idaho National Engineering Laboratory (DOE 1988b, Page 4-4). During construction, three to four associated test personnel would be required in addition to the construction force. After construction, there would be three years of testing and evaluation. In this period, the peak number of employees associated with the tests would be 11 plus some temporary duty professionals and personnel for waste preparation and handling. The existing infrastructure near the Idaho National Engineering Laboratory could easily accommodate the additional employees that would be needed to conduct the test program. The 11 or so employees that would be added to the Idaho National Engineering Laboratory work force and payroll would not alter the existing socioeconomic structure in southeastern Idaho.

The greatest socioeconomic impacts from conducting the bin-scale tests at a location other than the WIPP are projected to occur in southeast New Mexico. If no wastes were shipped to the WIPP during the five year period of conducting bin-scale tests away from the WIPP, activity at the WIPP would decrease to maintenance levels. The FY 1990 through FY 1994 funding level would be decreased by a total of $80 to $90 million or about $13.5 million in FY 1990 and $18 million a year from FY 1991 through FY 1994. The number of jobs would drop by 105 in FY 1990 and another 30 to 40 in FY 1991 until FY 1995 at which time, if test results were positive, spending at the WIPP would increase to levels approximating those of the Proposed Action.

Additional costs of approximately $430 million are estimated to be necessary to bring the WIPP operation back to the level needed to start accepting wastes and would include costs of rehiring, training, and reactivating facilities and programs.

Under this approach, 100 percent of the waste would need to be disposed of between FY 1995 and FY 2013 as opposed to 90 percent in the Proposed Action. The annual disposal workload would increase from an average of 4.7 percent of wastes under the Proposed Action to 5.3 percent. This would require additional resources to meet the same goal. The additional costs would be $7.4 million a year, or $74 million over the Disposal Phase. Considering the combination of additional costs associated with varying activity level and additional workloads, the total added cost could be $104 million. The net effect, additional costs minus net funding reductions of approximately $85 million, would be $19 million in constant dollars. The net cost in current dollars using a 3.5 percent projected inflation rate would be $66 million.

The reductions in activity that occur from FY 1990 through FY 1994 would have a temporary negative effect on the regional economy that is currently affected by low activity levels in two basic industries (potash mining and oil and gas production). However, the additional efforts associated with the FY 1995 through FY 2013 period would increase the projected WIPP related economic activity, employment, and personal income impacts by about 11 percent.

If the bin tests could not provide adequate information for a decision to proceed with the Disposal Phase, one option would be to conduct room-scale tests at the WIPP. This would again increase the resources needed to operate WIPP, particularly in the FY 2000 through the FY 2013 period. Instead of an increase of from 4.7 percent to 5.3 percent in annual wastes disposal requirements, the annual percentage increases to 6.4 percent. While the disposal activity level for FY 1995 through FY 1999 would be lower (2 percent a year), there would be no appreciable change in funding needs since the room-scale tests would be conducted in this period. The additional cost over the proposed action is estimated to be about $206 million. The net effect, added costs minus net funding reductions, is estimated at $121 million in constant 1990 dollars. The current net dollar cost would be $261 million, using a projected 3.5 percent annual inflation rate.

5.3.3 Land Use

Conducting the bin-scale test at the Idaho National Engineering Laboratory (or other DOE facilities) would have very little impact on the land uses at that DOE facility. The facility would require less than 0.25 acre of land for construction which is an insignificant amount of land area at the 890 mi^2 Idaho National Engineering Laboratory. The facility would, in all likelihood, be located near other active facilities at Idaho National Engineering Laboratory and thus on previously disturbed areas. The land at Idaho National Engineering Laboratory has been withdrawn from public use by the DOE and thus no conflict with other planned uses is anticipated.

5.3.4 Air Quality

Air quality at Idaho National Engineering Laboratory (or other DOE facilities) would be temporarily impacted by the construction of the test facility. Additional emissions of engine exhausts and fugitive dusts would occur. The engine exhaust emissions would be small compared to normal traffic on the Idaho National Engineering Laboratory site and fugitive dust is normally minimized by applying water to the construction zone.

Normal operations of the facility could potentially result in the release of extremely small amounts of radionuclides. The building would be maintained under negative pressure and all exhausts would be through HEPA filters. The small amount of radioactive materials to be used for bin-scale tests and the controlled nature of the test further reduce the possibility for a significant radionuclide release. The facility would be constructed and operated in compliance with applicable DOE Orders, and State and Federal regulations.

Impacts associated with operation of the WIPP after the bin-scale tests would be essentially the same as for the Proposed Action, if it is determined to proceed with such operations.

5.3.5 Cultural Resources

Cultural resource impacts can be avoided by careful location of the facility. Any proposed location would have cultural resource surveys performed prior to initiating construction activities. Additional reconnaissance would be provided during those construction activities requiring land disturbance.

Impacts associated with operation of the WIPP after the bin-scale tests would be the same as in the Proposed Action.

5.3.6 Water Quality

No impacts to the hydrology or water quality would result from the facility. Run-off during construction would be controlled. The facility would not normally discharge liquids. Any accidental release would be contained by engineered features of the facility.

5.3.7 Transportation

In the Alternative Action, only those tests that can be performed without placement of waste underground until there is a reasonable expectation of compliance with regulatory requirements would be conducted. TRU wastes would not be transported to WIPP until completion of the testing which is projected to require about five years.

5.3.7.1 Radiological Risks from Transportation. Following the Test Phase, 100 percent of the TRU waste volume would be sent to WIPP during a 20-year period which would increase the rate of receipt and emplacement activities over rates projected for the Proposed Action. Exposures are calculated as discussed in SEIS Subsection 5.2.2.1. Estimates of releases and exposures associated with the increased rate of TRU waste shipments during the 20-year Disposal Phase are provided in Tables 5.40-5.42. (For ease of comparison, many tables provide information relative to the Proposed Action and the Alternative Action; in SEIS Subsection 5.3, the Alternative Action information is "shaded.") Table 5.43 provides the health risks associated with transporting TRU wastes to the WIPP under the Alternative Action scenario. The annual number of excess fatal cancers for combined normal operations and accidents in the population along a WIPP transportation corridor are 2.0×10^{-2} and 1.4×10^{-2} for truck and rail transportation, respectively. The total annual excess fatal cancers for normal operations combined for

TABLE 5.40 Annual cumulative radiological exposures (person-rem) for CH TRU waste shipments for the Alternative Action

	Proposed Action		Proposed Action				Alternative Action			
	5 Yr Test Phase[a]		20 Yr Disposal Phase				20 Yr Disposal Phase			
	100% Truck		100% Truck		Maximum Rail		100% Truck		Maximum Rail	
Facility	Occupational[b]	Public[c]	Occupational	Public	Occupational	Public	Occupational	Public	Occupational	Public
Idaho National Engineering Laboratory										
Normal	$6.2x10^0$	$2.4x10^0$	$1.4x10^1$	$5.5x10^0$	$4.0x10^{-2}$	$4.2x10^0$	$1.6x10^1$	$6.0x10^0$	$4.4x10^{-2}$	$4.6x10^0$
Accident		$9.8x10^{-2}$		$2.2x10^{-1}$		$8.0x10^{-2}$		$2.4x10^{-1}$		$8.5x10^{-2}$
Rocky Flats Plant										
Normal	$6.8x10^0$	$1.7x10^0$	$1.6x10^1$	$3.8x10^0$	$5.0x10^{-2}$	$3.8x10^0$	$1.7x10^1$	$4.3x10^0$	$6.0x10^{-2}$	$4.3x10^0$
Accident		$3.4x10^{-2}$		$7.5x10^{-2}$		$3.6x10^{-2}$		$8.5x10^{-2}$		$4.1x10^{-2}$
Hanford Reservation										
Normal	$3.2x10^0$	$1.6x10^0$	$7.0x10^0$	$3.6x10^0$	$2.4x10^{-2}$	$3.6x10^0$	$8.0x10^0$	$4.0x10^0$	$2.6x10^{-2}$	$4.0x10^0$
Accident		$4.4x10^{-2}$		$1.0x10^{-1}$		$8.5x10^{-2}$		$1.1x10^{-1}$		$8.5x10^{-2}$
Savannah River Plant										
Normal	$8.8x10^0$	$4.4x10^0$	$2.0x10^1$	$1.0x10^1$	$6.0x10^{-2}$	$8.5x10^0$	$2.2x10^1$	$1.1x10^1$	$6.5x10^{-2}$	$9.5x10^0$
Accident						$2.8x10^0$		$6.5x10^0$		$3.1x10^0$
						$1.2x10^0$	$4.2x10^0$	$1.4x10^0$	$4.0x10^0$	$1.4x10^0$
						$1.4x10^{-1}$		$1.6x10^{-1}$		$1.6x10^{-1}$
	$7.6x10^{-1}$	$1.2x10^0$	$1.6x10^0$	$2.7x10^0$	$1.4x10^{-2}$	$1.4x10^0$	$1.8x10^0$	$3.0x10^0$	$1.5x10^{-2}$	$1.4x10^0$
Accident		$3.4x10^{-2}$		$7.5x10^{-2}$		$3.6x10^{-2}$		$8.5x10^{-2}$		$4.0x10^{-2}$
Nevada Test Site[d]										
Normal	$1.2x10^{-1}$	$4.8x10^{-2}$	$2.8x10^{-1}$	$1.1x10^{-1}$	$2.8x10^{-1}$	$1.1x10^{-1}$	$3.0x10^{-1}$	$1.2x10^{-1}$	$3.0x10^{-1}$	$1.2x10^{-1}$
Accident		$2.2x10^{-5}$		$4.8x10^{-5}$		$4.8x10^{-5}$		$5.5x10^{-5}$		$5.5x10^{-5}$

5 5-95 Table 5.40 In Alternative Action, 20-Yr Disposal Phase, 100% truck, Occupation column: fifth number from top, 4.2×10^0, should read 4.1×10^0.

Normal operations of the facility could potentially result in the release of extremely small amounts of radionuclides. The building would be maintained under negative pressure and all exhausts would be through HEPA filters. The small amount of radioactive materials to be used for bin-scale tests and the controlled nature of the test further reduce the possibility for a significant radionuclide release. The facility would be constructed and operated in compliance with applicable DOE Orders, and State and Federal regulations.

Impacts associated with operation of the WIPP after the bin-scale tests would be essentially the same as for the Proposed Action, if it is determined to proceed with such operations.

5.3.5 **Cultural Resources**

Cultural resource impacts can be avoided by careful location of the facility. Any proposed location would have cultural resource surveys performed prior to initiating construction activities. Additional reconnaissance would be provided during those construction activities requiring land disturbance.

Impacts associated with operation of the WIPP after the bin-scale tests would be the same as in the Proposed Action.

5.3.6 **Water Quality**

No impacts to the hydrology or water quality would result from the facility. Run-off during construction would be controlled. The facility would not normally discharge liquids. Any accidental release would be contained by engineered features of the facility.

5.3.7 **Transportation**

In the Alternative Action, only those tests that can be performed without placement of waste underground until there is a reasonable expectation of compliance with regulatory requirements would be conducted. TRU wastes would not be transported to WIPP until completion of the testing which is projected to require about five years.

5.3.7.1 Radiological Risks from Transportation. Following the Test Phase, 100 percent of the TRU waste volume would be sent to WIPP during a 20-year period which would increase the rate of receipt and emplacement activities over rates projected for the Proposed Action. Exposures are calculated as discussed in SEIS Subsection 5.2.2.1. Estimates of releases and exposures associated with the increased rate of TRU waste shipments during the 20-year Disposal Phase are provided in Tables 5.40-5.42. (For ease of comparison, many tables provide information relative to the Proposed Action and the Alternative Action; in SEIS Subsection 5.3, the Alternative Action information is "shaded.") Table 5.43 provides the health risks associated with transporting TRU wastes to the WIPP under the Alternative Action scenario. The annual number of excess fatal cancers for combined normal operations and accidents in the population along a WIPP transportation corridor are 2.0×10^{-2} and 1.4×10^{-2} for truck and rail transportation, respectively. The total annual excess fatal cancers for normal operations combined for

TABLE 5.40 Annual cumulative radiological exposures (person-rem) for CH TRU waste shipments for the Alternative Action

	Proposed Action 5 Yr Test Phase[a]		Proposed Action 20 Yr Disposal Phase				Alternative Action 20 Yr Disposal Phase			
	100% Truck		100% Truck		Maximum Rail		100% Truck		Maximum Rail	
Facility	Occupational[b]	Public[c]	Occupational	Public	Occupational	Public	Occupational	Public	Occupational	Public
Idaho National Engineering Laboratory										
Normal	6.2×10^{0}	2.4×10^{0}	1.4×10^{1}	5.5×10^{0}	4.0×10^{-2}	4.2×10^{0}	1.6×10^{1}	6.0×10^{0}	4.4×10^{-2}	4.6×10^{0}
Accident		9.8×10^{-2}		2.2×10^{-1}		8.0×10^{-2}		2.4×10^{-1}		8.5×10^{-2}
Rocky Flats Plant										
Normal	6.8×10^{0}	1.7×10^{0}	1.6×10^{1}	3.8×10^{0}	5.0×10^{-2}	3.8×10^{0}	1.7×10^{1}	4.3×10^{0}	6.0×10^{-2}	4.3×10^{0}
Accident		3.4×10^{-2}		7.5×10^{-2}		3.6×10^{-2}		8.5×10^{-2}		4.1×10^{-2}
Hanford Reservation										
Normal	3.2×10^{0}	1.6×10^{0}	7.0×10^{0}	3.6×10^{0}	2.4×10^{-2}	3.6×10^{0}	8.0×10^{0}	4.0×10^{0}	2.6×10^{-2}	4.0×10^{0}
Accident		4.4×10^{-2}		1.0×10^{-1}		8.5×10^{-2}		1.1×10^{-1}		8.5×10^{-2}
Savannah River Plant										
Normal	8.8×10^{0}	4.4×10^{0}	2.0×10^{1}	1.0×10^{1}	6.0×10^{-2}	8.5×10^{0}	2.2×10^{1}	1.1×10^{1}	6.5×10^{-2}	9.5×10^{0}
Accident		2.6×10^{0}		6.0×10^{0}		2.8×10^{0}		6.5×10^{0}		3.1×10^{0}
Los Alamos National Laboratory[d]										
Normal	1.6×10^{0}	5.4×10^{-1}	3.6×10^{0}	1.2×10^{0}	3.6×10^{0}	1.2×10^{0}	4.2×10^{0}	1.4×10^{0}	4.0×10^{0}	1.4×10^{0}
Accident		6.6×10^{-2}		1.0×10^{-1}		1.4×10^{-1}		1.6×10^{-1}		1.6×10^{-1}
Oak Ridge National Laboratory										
Normal	7.6×10^{-1}	1.2×10^{0}	1.6×10^{0}	2.7×10^{0}	1.4×10^{-2}	1.4×10^{0}	1.8×10^{0}	3.0×10^{0}	1.5×10^{-2}	1.4×10^{0}
Accident		3.4×10^{-2}		7.5×10^{-2}		3.6×10^{-2}		8.5×10^{-2}		4.0×10^{-2}
Nevada Test Site[d]										
Normal	1.2×10^{-1}	4.8×10^{-2}	2.8×10^{-1}	1.1×10^{-1}	2.8×10^{-1}	1.1×10^{-1}	3.0×10^{-1}	1.2×10^{-1}	3.0×10^{-1}	1.2×10^{-1}
Accident		2.2×10^{-5}		4.8×10^{-5}		4.8×10^{-5}		5.5×10^{-5}		5.5×10^{-5}

TABLE 5.40 Concluded

	Proposed Action 5 Yr Test Phase		Proposed Action 20 Yr Disposal Phase				Alternative Action 20 Yr Disposal Phase			
	100% Truck		100% Truck		Maximum Rail		100% Truck		Maximum Rail	
	Occupational[b]	Public[c]	Occupational	Public	Occupational	Public	Occupational	Public	Occupational	Public
Argonne National Laboratory - East										
Normal	5.2×10^{-2}	5.6×10^{-2}	9.0×10^{-2}	1.1×10^{-1}	6.5×10^{-4}	6.5×10^{-2}	1.0×10^{-1}	1.1×10^{-1}	7.0×10^{-4}	7.5×10^{-2}
Accident		1.9×10^{-4}		3.4×10^{-4}		1.2×10^{-4}		3.9×10^{-4}		1.1×10^{-4}
Lawrence Livermore National Laboratory										
Normal	4.4×10^{-1}	2.2×10^{-1}	1.0×10^{0}	4.9×10^{-1}	3.0×10^{-3}	4.9×10^{-1}	1.1×10^{0}	5.5×10^{-1}	3.3×10^{-3}	5.5×10^{-1}
Accident						8.0×10^{-2}		1.2×10^{-1}		9.5×10^{-2}
						2.9×10^{-2}	1.7×10^{-1}	8.5×10^{-2}	4.7×10^{-4}	4.3×10^{-2}
						2.0×10^{-6}		5.0×10^{-6}		2.3×10^{-6}
						2.3×10^{1}	7.1×10^{1}	3.1×10^{1}	4.5×10^{0}	2.6×10^{1}
						3.3×10^{0}	--	7.3×10^{0}	—	3.6×10^{0}
						2.6×10^{1}	7.1×10^{1}	3.8×10^{1}	4.5×10^{0}	3.0×10^{1}

[a] Assumes 10 percent of shipments from all generator facilities to provide upper bound of risk during this Test Phase; all shipments are made by truck.

[b] Occupational Population is all the transportation crews.

[c] Nonoccupational population.

[d] Waste shipments limited to truck mode. Rail risks are the same as truck risks.

5 5-96 Table 5.40 In Proposed Action, 20-yr Disposal Phase, Maximum Rail, Public column: fifth number from top, 2.9×10^{-2}, should read 3.8×10^{-2}.

5 5-96 Table 5.40 In Alternative Action, 20-yr Disposal Phase, Maximum rail, Public column: sixth number from top, 2.3×10^{-6}, should read 2.3×10^{-1}.

TABLE 5.41 Annual cumulative radiological exposures (person-rem) for RH TRU waste shipments for the Alternative Action

Facility	Proposed action[a] 20 Yr Disposal Phase				Alternative Action 20 Yr Disposal Phase			
	100% Truck		Maximum Rail		100% Truck		Maximum Rail	
	Occupational[b]	Public[c]	Occupational	Public	Occupational	Public	Occupational	Public
Idaho National Engineering Laboratory								
Normal	$9.5x10^{-1}$	$7.5x10^{-1}$	$6.0x10^{-3}$	$6.0x10^{-1}$	$9.5x10^{-1}$	$7.5x10^{-1}$	$6.0x10^{-3}$	$6.0x10^{-1}$
Accident		$1.7x10^{-5}$		$7.0x10^{-6}$		$1.7x10^{-5}$		$7.0x10^{-6}$
Hanford Reservation								
Normal	$8.0x10^{0}$	$1.6x10^{1}$	$8.0x10^{-2}$	$7.0x10^{0}$	$8.0x10^{0}$	$1.6x10^{1}$	$8.0x10^{-2}$	$7.0x10^{0}$
Accident		$2.9x10^{0}$		$1.4x10^{0}$		$2.9x10^{0}$		$1.4x10^{0}$
Los Alamos National Laboratory								
Normal	$6.0x10^{-2}$	$2.0x10^{-2}$	$6.0x10^{-2}$	$2.0x10^{-2}$	$6.0x10^{-2}$	$2.0x10^{-2}$	$6.0x10^{-2}$	$2.0x10^{-2}$
Accident		$8.5x10^{-6}$		$8.5x10^{-6}$		$8.5x10^{-6}$		$8.5x10^{-6}$
Oak Ridge National Laboratory[b]								
Normal	$2.1x10^{1}$	$1.4x10^{1}$	$1.3x10^{-1}$	$1.2x10^{1}$	$2.1x10^{1}$	$1.4x10^{1}$	$1.3x10^{-1}$	$1.2x10^{1}$
Accident		$2.0x10^{-3}$		$2.8x10^{-4}$		$2.0x10^{-3}$		$2.8x10^{-4}$
Argonne National Laboratory - East								
Normal	$2.2x10^{-2}$	$1.8x10^{-2}$	$1.3x10^{-4}$	$1.2x10^{-2}$	$2.2x10^{-2}$	$1.8x10^{-2}$	$1.3x10^{-4}$	$1.2x10^{-2}$
Accident		$2.9x10^{-6}$		$1.3x10^{-6}$		$2.9x10^{-6}$		$1.3x10^{-6}$
Cumulative Risk								
Normal	$3.0x10^{1}$	$3.1x10^{1}$	$2.8x10^{-1}$	$2.0x10^{1}$	$3.0x10^{1}$	$3.1x10^{1}$	$2.8x10^{-1}$	$2.0x10^{1}$
Accident	---	$2.9x10^{0}$	---	$1.4x10^{0}$		$2.9x10^{0}$		$1.4x10^{0}$
TOTAL	$3.0x10^{1}$	$3.4x10^{1}$	$2.8x10^{-1}$	$2.1x10^{1}$	$3.0x10^{1}$	$3.4x10^{1}$	$2.8x10^{-1}$	$2.1x10^{1}$

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[a] No RH wastes are assumed during the Test Phase -- therefore postulated exposures for RH waste shipments are the same for either scenario.

[b] Occupational population is the total transportation crews.

[c] Nonoccupational population.

[d] To increase projected TRU waste volumes to WIPP maximum capacity, additional volumes of RH-TRU waste than known at present were assumed to originate at Oak Ridge National Laboratory.

TABLE 5.40 Concluded

	Proposed Action 5 Yr Test Phase		Proposed Action 20 Yr Disposal Phase				Alternative Action 20 Yr Disposal Phase			
	100% Truck		100% Truck		Maximum Rail		100% Truck		Maximum Rail	
	Occupational[b]	Public[c]	Occupational	Public	Occupational	Public	Occupational	Public	Occupational	Public
Argonne National Laboratory - East										
Normal	$5.2x10^{-2}$	$5.6x10^{-2}$	$9.0x10^{-2}$	$1.1x10^{-1}$	$6.5x10^{-4}$	$6.5x10^{-2}$	$1.0x10^{-1}$	$1.1x10^{-1}$	$7.0x10^{-4}$	$7.5x10^{-2}$
Accident		$1.9x10^{-4}$		$3.4x10^{-4}$		$1.2x10^{-4}$		$3.9x10^{-4}$		$1.1x10^{-4}$
Lawrence Livermore National Laboratory										
Normal	$4.4x10^{-1}$	$2.2x10^{-1}$	$1.0x10^{0}$	$4.9x10^{-1}$	$3.0x10^{-3}$	$4.9x10^{-1}$	$1.1x10^{0}$	$5.5x10^{-1}$	$3.3x10^{-3}$	$5.5x10^{-1}$
ccident		$4.6x10^{-2}$		$1.0x10^{-1}$		$8.0x10^{-2}$		$1.2x10^{-1}$		$9.5x10^{-2}$
lound Plant										
ormal	$6.8x10^{-2}$	$3.4x10^{-2}$	$1.5x10^{-1}$	$7.5x10^{-2}$	$1.7x10^{-4}$	$2.9x10^{-2}$	$1.7x10^{-1}$	$8.5x10^{-2}$	$4.7x10^{-4}$	$4.3x10^{-2}$
ccident		$2.0x10^{-6}$		$4.7x10^{-6}$		$2.0x10^{-6}$		$5.0x10^{-6}$		$2.3x10^{-6}$
umulative Risk										
al	$2.8x10^{1}$	$1.2x10^{1}$	$6.4x10^{1}$	$2.8x10^{1}$	$4.1x10^{0}$	$2.3x10^{1}$	$7.1x10^{1}$	$3.1x10^{1}$	$4.5x10^{0}$	$2.6x10^{1}$
ent	---	$2.9x10^{0}$	---	$6.7x10^{0}$	---	$3.3x10^{0}$	---	$7.3x10^{0}$	---	$3.6x10^{0}$
L	$2.8x10^{1}$	$1.5x10^{1}$	$6.4x10^{1}$	$3.5x10^{1}$	$4.1x10^{0}$	$2.6x10^{1}$	$7.1x10^{1}$	$3.8x10^{1}$	$4.5x10^{0}$	$3.0x10^{1}$

Assumes 10 percent of shipments from all generator facilities to provide upper bound of risk during this Test Phase; all shipments are made by truck.

[b] Occupational Population is all the transportation crews.

[c] Nonoccupational population.

[d] Waste shipments limited to truck mode. Rail risks are the same as truck risks.

TABLE 5.41 Annual cumulative radiological exposures (person-rem) for RH TRU waste shipments for the Alternative Action

Facility	Proposed action[a] 20 Yr Disposal Phase				Alternative Action 20 Yr Disposal Phase			
	100% Truck		Maximum Rail		100% Truck		Maximum Rail	
	Occupational[b]	Public[c]	Occupational	Public	Occupational	Public	Occupational	Public
Idaho National Engineering Laboratory								
Normal	$9.5x10^{-1}$	$7.5x10^{-1}$	$6.0x10^{-3}$	$6.0x10^{-1}$	$9.5x10^{-1}$	$7.5x10^{-1}$	$6.0x10^{-3}$	$6.0x10^{-1}$
Accident		$1.7x10^{-5}$		$7.0x10^{-6}$		$1.7x10^{-5}$		$7.0x10^{-6}$
Hanford Reservation								
Normal	$8.0x10^{0}$	$1.6x10^{1}$	$8.0x10^{-2}$	$7.0x10^{0}$	$8.0x10^{0}$	$1.6x10^{1}$	$8.0x10^{-2}$	$7.0x10^{0}$
Accident		$2.9x10^{0}$		$1.4x10^{0}$		$2.9x10^{0}$		$1.4x10^{0}$
Los Alamos National Laboratory								
Normal	$6.0x10^{-2}$	$2.0x10^{-2}$	$6.0x10^{-2}$	$2.0x10^{-2}$	$6.0x10^{-2}$	$2.0x10^{-2}$	$6.0x10^{-2}$	$2.0x10^{-2}$
Accident		$8.5x10^{-6}$		$8.5x10^{-6}$		$8.5x10^{-6}$		$8.5x10^{-6}$
Oak Ridge National Laboratory[b]								
Normal	$2.1x10^{1}$	$1.4x10^{1}$	$1.3x10^{-1}$	$1.2x10^{1}$	$2.1x10^{1}$	$1.4x10^{1}$	$1.3x10^{-1}$	$1.2x10^{1}$
Accident		$2.0x10^{-3}$		$2.8x10^{-4}$		$2.0x10^{-3}$		$2.8x10^{-4}$
Argonne National Laboratory - East								
Normal	$2.2x10^{-2}$	$1.8x10^{-2}$	$1.3x10^{-4}$	$1.2x10^{-2}$	$2.2x10^{-2}$	$1.8x10^{-2}$	$1.3x10^{-4}$	$1.2x10^{-2}$
Accident		$2.9x10^{-6}$		$1.3x10^{-6}$		$2.9x10^{-6}$		$1.3x10^{-6}$
Cumulative Risk								
Normal	$3.0x10^{1}$	$3.1x10^{1}$	$2.8x10^{-1}$	$2.0x10^{1}$	$3.0x10^{1}$	$3.1x10^{1}$	$2.8x10^{-1}$	$2.0x10^{1}$
Accident	---	$2.9x10^{0}$	---	$1.4x10^{0}$		$2.9x10^{0}$		$1.4x10^{0}$
TOTAL	$3.0x10^{1}$	$3.4x10^{1}$	$2.8x10^{-1}$	$2.1x10^{1}$	$3.0x10^{1}$	$3.4x10^{1}$	$2.8x10^{-1}$	$2.1x10^{1}$

[a] No RH wastes are assumed during the Test Phase -- therefore postulated exposures for RH waste shipments are the same for either scenario.

[b] Occupational population is the total transportation crews.

[c] Nonoccupational population.

[d] To increase projected TRU waste volumes to WIPP maximum capacity, additional volumes of RH-TRU waste than known at present were assumed to originate at Oak Ridge National Laboratory.

TABLE 5.42 Hypothetical maximum exposure (rem) to any individual from Alternative Action incident-free transportation[a]

	Proposed Action				Alternative Action			
	100% Truck		Maximum Rail		100% Truck		Maximum Rail	
Shipment Origin Site	CH	RH	CH	RH	CH	RH	CH	RH
Idaho National Engineering Laboratory	$2.3x10^{-4}$	$2.4x10^{-5}$	$2.2x10^{-4}$	$2.5x10^{-5}$	$2.3x10^{-4}$	$2.4x10^{-5}$	$2.2x10^{-4}$	$2.5x10^{-5}$
Rocky Flats Plant	$4.7x10^{-4}$	---	$4.7x10^{-4}$	---	$4.7x10^{-4}$	---	$4.7x10^{-4}$	---
Hanford Reservation	$1.0x10^{-4}$	$4.0x10^{-4}$	$1.0x10^{-4}$	$4.0x10^{-4}$	$1.0x10^{-4}$	$4.0x10^{-4}$	$1.0x10^{-4}$	$4.0x10^{-4}$
Savannah River Plant	$3.1x10^{-4}$	---	$3.1x10^{-4}$	---	$3.1x10^{-4}$	---	$3.1x10^{-4}$	---
Los Alamos National Laboratory[b]	$4.0x10^{-4}$	$9.4x10^{-6}$	$4.0x10^{-4}$	$9.4x10^{-6}$	$4.0x10^{-4}$	$9.4x10^{-6}$	$4.0x10^{-4}$	$9.4x10^{-6}$
Oak Ridge National Laboratory	$1.1x10^{-4}$	$5.8x10^{-4}$	$1.1x10^{-4}$	$5.8x10^{-4}$	$1.1x10^{-4}$	$5.8x10^{-4}$	$1.1x10^{-4}$	$5.8x10^{-4}$
Nevada Test Site[b]	$5.3x10^{-6}$	---	$5.3x10^{-6}$	---	$5.3x10^{-6}$	---	$5.3x10^{-6}$	---
Argonne National Laboratory - East	$4.3x10^{-6}$	$6.1x10^{-7}$	$4.4x10^{-6}$	$8.0x10^{-7}$	$4.3x10^{-6}$	$6.1x10^{-7}$	$4.4x10^{-6}$	$8.0x10^{-7}$
Lawrence Livermore National Laboratory	$1.6x10^{-5}$	---	$1.6x10^{-5}$	--	$1.6x10^{-5}$	---	$1.6x10^{-5}$	---
					$2.5x10^{-6}$	---	$2.6x10^{-6}$	---
					$1.6x10^{-3}$	$1.0x10^{-3}$	$1.6x10^{-3}$	$1.0x10^{-3}$

5 5-98 Table 5.42 In Proposed Action, 100% Truck, RH column: last number in column, 1.1×10^{-3}, should read 1.0×10^{-3}.

5 5-98 Table 5.42 All Alternative Action columns should be shaded.

5 5-98 Table 5.42 In Alternative Action, Maximum Rail, RH column: last number, 1.0×10^{-3}, should read 1.1×10^{-3}.

TABLE 5.43 Human health risks associated with radiological exposures during Alternative Action transportation

Transportation Activity	Maximum Annual Health Risk[a,b,c] (latent cancer fatalities/year)					
	Occupational			Public		
	Proposed Action			Proposed Action		
	Test Phase	Operational Period	Alternative Action	Test Phase	Proposed Action	Alternative Action
100% Truck Normal	7.8×10^{-3}	2.6×10^{-2}	2.8×10^{-2}	3.4×10^{-3}	1.6×10^{-2}	1.7×10^{-2}
Accident	- - -	- - -	- - -	8.1×10^{-4}	2.7×10^{-3}	2.8×10^{-3}
TOTAL	7.8×10^{-3}	2.6×10^{-2}	2.8×10^{-2}	4.2×10^{-3}	1.9×10^{-2}	2.0×10^{-2}
					7.6×10^{-7}	7.3×10^{-7}
					1.1×10^{-2}	1.3×10^{-2}
					2.3×10^{-3}	1.4×10^{-3}
					1.3×10^{-2}	1.4×10^{-2}
					5.9×10^{-7}	7.3×10^{-7}

5-99 5

5-99 Table 5.43 In Public, Proposed Action column:

(1) Fourth number from top, 7.6×10^{-7}, should read 7.3×10^{-7}.

(2) Fifth number from top, 1.1×10^{-2}, should read 1.2×10^{-2}.

(3) Sixth number from top, 2.3×10^{-3}, should read 1.3×10^{-3}.

(4) Eighth number from top, 5.9×10^{-7}, should read 7.6×10^{-7}.

5 5-99 Table 5.43 In Public, Alternative Action column: last number in the column, 7.8×10^{-7}, should read 7.6×10^{-7}.

ɔsed population along the shipping routes (both CH and RH
valent to 1.0 chance of a cancer in 1,000 for each year of

sks presented in the table for cancer fatality risks.

e to the WIPP (assumed to be living 30 meters from

TABLE 5.42 Hypothetical maximum exposure (rem) to any individual from Alternative Action incident-free transportation[a]

	Proposed Action				Alternative Action			
	100% Truck		Maximum Rail		100% Truck		Maximum Rail	
Shipment Origin Site	CH	RH	CH	RH	CH	RH	CH	RH
Idaho National Engineering Laboratory	2.3×10^{-4}	2.4×10^{-5}	2.2×10^{-4}	2.5×10^{-5}	2.3×10^{-4}	2.4×10^{-5}	2.2×10^{-4}	2.5×10^{-5}
Rocky Flats Plant	4.7×10^{-4}	---	4.7×10^{-4}	---	4.7×10^{-4}	---	4.7×10^{-4}	---
Hanford Reservation	1.0×10^{-4}	4.0×10^{-4}	1.0×10^{-4}	4.0×10^{-4}	1.0×10^{-4}	4.0×10^{-4}	1.0×10^{-4}	4.0×10^{-4}
Savannah River Plant	3.1×10^{-4}	---	3.1×10^{-4}	---	3.1×10^{-4}	---	3.1×10^{-4}	---
Los Alamos National Laboratory[b]	4.0×10^{-4}	9.4×10^{-6}	4.0×10^{-4}	9.4×10^{-6}	4.0×10^{-4}	9.4×10^{-6}	4.0×10^{-4}	9.4×10^{-6}
Oak Ridge National Laboratory	1.1×10^{-4}	5.8×10^{-4}	1.1×10^{-4}	5.8×10^{-4}	1.1×10^{-4}	5.8×10^{-4}	1.1×10^{-4}	5.8×10^{-4}
Nevada Test Site[b]	5.3×10^{-6}	---	5.3×10^{-6}	---	5.3×10^{-6}	---	5.3×10^{-6}	---
Argonne National Laboratory - East	4.3×10^{-6}	6.1×10^{-7}	4.4×10^{-6}	8.0×10^{-7}	4.3×10^{-6}	6.1×10^{-7}	4.4×10^{-6}	8.0×10^{-7}
Lawrence Livermore National Laboratory	1.6×10^{-5}	---	1.6×10^{-5}	---	1.6×10^{-5}	---	1.6×10^{-5}	---
Mound Plant	2.5×10^{-6}	---	2.6×10^{-6}	---	2.5×10^{-6}	---	2.6×10^{-6}	---
TOTAL	1.6×10^{-3}	1.1×10^{-3}	1.6×10^{-3}	1.1×10^{-3}	1.6×10^{-3}	1.0×10^{-3}	1.6×10^{-3}	1.0×10^{-3}

Hypothetical maximum individual is exposed to all TRU waste shipments to the WIPP.

Waste shipments are limited to the truck mode. Rail risks are thus the same as truck risks.

TABLE 5.43 Human health risks associated with radiological exposures during Alternative Action transportation

	Maximum Annual Health Risk[a,b,c] (latent cancer fatalities/year					
	Occupational			Public		
	Proposed Action			Proposed Action		
Transportation Activity	Test Phase	Operational Period	Alternative Action	Test Phase	Proposed Action	Alternative Action
100% Truck Normal	$7.8x10^{-3}$	$2.6x10^{-2}$	$2.8x10^{-2}$	$3.4x10^{-3}$	$1.6x10^{-2}$	$1.7x10^{-2}$
Accident	- - -	- - -	- - -	$8.1x10^{-4}$	$2.7x10^{-3}$	$2.8x10^{-3}$
TOTAL	$7.8x10^{-3}$	$2.6x10^{-2}$	$2.8x10^{-2}$	$4.2x10^{-3}$	$1.9x10^{-2}$	$2.0x10^{-2}$
Hypothetical Maximum[d] Exposed Individual					$7.6x10^{-7}$	$7.3x10^{-7}$
Maximum Rail Normal	- - -	$1.2x10^{-3}$	$1.3x10^{-3}$	- - -	$1.1x10^{-2}$	$1.3x10^{-2}$
Accident	- - -	- - -	- - -	- - -	$2.3x10^{-3}$	$1.4x10^{-3}$
TOTAL	- - -	$1.2x10^{-3}$	$1.3x10^{-3}$	- - -	$1.3x10^{-2}$	$1.4x10^{-2}$
Hypothetical Maximum[d] Exposed Individual					$5.9x10^{-7}$	$7.3x10^{-7}$

[a] Transportation health risks are expressed as the annual number of excess fatal cancers in the entire exposed population along the shipping routes (both CH and RH TRU waste shipments are included). Risks are expressed in exponential form (i.e., $1.0 \text{ x } 10^{-3}$ is equivalent to 1.0 chance of a cancer in 1,000 for each year of operation).

[b] Risk of contracting fatal cancer: $2.8 \text{ x } 10^{-4}$ fatalities/person-rem.

[c] Annual health effects risk estimates for genetic effects would be somewhat less (a factor of 0.918) than the risks presented in the table for cancer fatality risks.

[d] Risk expressed as that individual's chance of contracting a fatal cancer due to the transportation of waste to the WIPP (assumed to be living 30 meters from transportation routes at the WIPP boundary).

transportation workers are estimated to be 2.8x 10^{-2} and 1.3 x 10^{-3} for truck and rail transportation, respectively. Also, the maximum excess risk to a hypothetical individual exposed to all shipments to the WIPP is 0.73 chances per million of contracting a fatal cancer.

5	5-100	first ¶, lines 2 & 3	Sentence beginning with "also" should read, "Also, the maximum excess risk to a hypothetical individual exposed to all shipments to the WIPP is 0.73 and 0.76 chances per million of contracting a fatal cancer for truck and maximum rail transport, respectively."	even atory ·year ng a s .14 ·CFs, iative

Action are the same as the Proposed Action and are presented in SEIS Subsection 5.2.2.

5.3.8 Radiological Assessment: Operations

Radiological exposures associated with conducting the bin-scale tests are expected to be small compared to present exposures at the suggested locations because the quantities of TRU waste associated with the tests are small. The facility to conduct the tests would be sited, permitted, constructed, reviewed and operated in compliance with applicable regulations and standards.

TRU wastes would not be transported to WIPP until completion of the testing which is projected to require about five years. Following the Test Phase, 100 percent of the TRU waste volume would be sent to the WIPP during a 20-year Disposal Phase which would increase the rate of receipt and emplacement activities over rates projected for the proposed action. Estimates of releases and exposures associated with the increased rate of TRU waste shipments during the 20-year Disposal Phase are provided in Tables 5.44-5.46. Releases and exposures were calculated using the same methods and assumptions provided in SEIS Subsection 5.2.3 and Appendix F, but with the higher annual throughputs associated with the Alternative Action.

Tables 5.47 and 5.48 provide estimates of the annual health impacts associated with routine and severe accidental radiological releases, respectively. As discussed in SEIS Subsection 5.2.3, the excess risk of incurring a fatal cancer was assumed to be 2.8 cancers per 10,000 person-rem of exposure to a population. The annual occupational excess risk of contracting a fatal cancer from routine operations is about 2.8 in 10,000. The maximum individual excess risk of cancer is 19 in one million (1.9 x 10^{-8}). The excess risk of contracting a fatal cancer to the entire population within 50 miles of the WIPP is 26 in one million (2.6 x 10^{-5}) per year of normal population distributed throughout the total population of 95,810.

It is postulated that accident scenarios discussed in SEIS Subsection 5.2.3 for the proposed action are also appropriate for the Alternative Action. Table 5.48 shows health risks associated with radiation exposures during postulated accidents in comparison to those in the FEIS. Occupational workers will incur an estimated 26 in 10,000 (2.6 x 10^{-3}) excess risk of contracting a fatal cancer.

5 5-101 Table 5.44 Heading over Test Phase and Disposal Phase should read "Proposed Action."

TABLE 5.44 Alternative Action routine radionuclide releases to the WIPP environment (total activity in Curies/year)

	Phase[a]		Phase[b]		Alternative Action[c]	
Isotope	WHB[d]	SE[e]	WHB	SE	WHB	SE
Co-60	---[f]	---	7.4×10^{-12}	3.5×10^{-5}	7.4×10^{-12}	3.5×10^{-5}
Sr-90	---	---	2.2×10^{-10}	1.0×10^{-3}	2.2×10^{-10}	1.0×10^{-3}
Ru-106	---	---	1.5×10^{-12}	7.2×10^{-6}	1.5×10^{-12}	7.2×10^{-6}
Sb-125	---	---	4.8×10^{-14}	2.3×10^{-7}	4.8×10^{-14}	2.3×10^{-7}
Cs-137	---	---	1.9×10^{-10}	8.8×10^{-4}	1.9×10^{-10}	8.8×10^{-4}
Ce-144	---	---	1.5×10^{-11}	6.9×10^{-5}	1.5×10^{-11}	6.9×10^{-5}
Th-232	7.5×10^{-18}	3.5×10^{-11}	1.7×10^{-17}	8.0×10^{-11}	1.9×10^{-17}	8.8×10^{-11}
U-233	3.4×10^{-13}	1.6×10^{-6}	8.0×10^{-13}	3.8×10^{-6}	8.8×10^{-13}	4.2×10^{-6}
U-235	7.1×10^{-16}	3.3×10^{-9}	1.2×10^{-13}	5.7×10^{-7}	1.2×10^{-13}	5.7×10^{-7}
U-238	1.0×10^{-16}	4.9×10^{-10}	1.0×10^{-14}	4.8×10^{-8}	1.0×10^{-14}	4.8×10^{-8}
Np-237	3.4×10^{-16}	1.6×10^{-9}	7.6×10^{-16}	3.6×10^{-9}	8.5×10^{-16}	4.0×10^{-9}
Pu-238	2.8×10^{-11}	1.3×10^{-4}	1.0×10^{-10}	4.8×10^{-4}	1.1×10^{-10}	5.1×10^{-4}
Pu-239	2.5×10^{-11}	1.2×10^{-4}	1.0×10^{-10}	4.8×10^{-4}	1.1×10^{-10}	5.0×10^{-4}
Pu-240	7.4×10^{-12}	3.5×10^{-5}	3.1×10^{-11}	1.5×10^{-4}	3.3×10^{-11}	1.6×10^{-4}
Pu-241	6.6×10^{-10}	3.1×10^{-3}	2.0×10^{-9}	9.4×10^{-3}	2.1×10^{-9}	1.0×10^{-2}
Pu-242	1.4×10^{-15}	6.7×10^{-9}	5.7×10^{-15}	2.7×10^{-8}	6.1×10^{-15}	2.9×10^{-8}
Am-241	3.7×10^{-11}	1.8×10^{-4}	8.8×10^{-11}	4.2×10^{-4}	9.8×10^{-11}	4.6×10^{-4}
Cm-244	1.1×10^{-13}	5.1×10^{-7}	1.3×10^{-12}	6.2×10^{-6}	1.4×10^{-12}	6.4×10^{-6}
Cf-252	2.7×10^{-14}	1.2×10^{-7}	1.9×10^{-12}	8.8×10^{-6}	1.9×10^{-12}	8.8×10^{-6}
Total	7.6×10^{-10}	3.6×10^{-3}	2.8×10^{-9}	1.3×10^{-2}	2.9×10^{-9}	1.4×10^{-2}

[a] Based on annual throughput equivalent to about 22,000 CH drums.

[b] Based on annual throughput equivalent to about 49,500 CH drums and 400 RH canisters.

[c] Based on annual throughput equivalent to about 55,000 CH drums and 400 RH canisters.

[d] WHB = Waste Handling Building.

[e] SE = Storage exhaust.

[f] Blanks = Isotope not present during Test Phase.

transportation workers are estimated to be 2.8x 10^{-2} and 1.3 x 10^{-3} for truck and rail transportation, respectively. Also, the maximum excess risk to a hypothetical individual exposed to all shipments to the WIPP is 0.73 chances per million of contracting a fatal cancer.

5.3.7.2 Nonradiological Risks from Transportation. In the Alternative Action, seven shipments from the Rocky Flats Plant to the Idaho National Engineering Laboratory would be required for the bin tests. The bin tests would be conducted over a five-year period, and then TRU waste from all facilities would be shipped to the WIPP during a 20-year period. The estimated risk for truck shipments in the Alternative Action is .14 LCFs, 6.1 fatalities, and 79 injuries. For the rail mode, the estimated risk is .88 LCFs, 2 fatalities, and 21 injuries. The risks of shipping RH TRU waste for the Alternative Action are the same as the Proposed Action and are presented in SEIS Subsection 5.2.2.

5.3.8 **Radiological Assessment: Operations**

Radiological exposures associated with conducting the bin-scale tests are expected to be small compared to present exposures at the suggested locations because the quantities of TRU waste associated with the tests are small. The facility to conduct the tests would be sited, permitted, constructed, reviewed and operated in compliance with applicable regulations and standards.

TRU wastes would not be transported to WIPP until completion of the testing which is projected to require about five years. Following the Test Phase, 100 percent of the TRU waste volume would be sent to the WIPP during a 20-year Disposal Phase which would increase the rate of receipt and emplacement activities over rates projected for the proposed action. Estimates of releases and exposures associated with the increased rate of TRU waste shipments during the 20-year Disposal Phase are provided in Tables 5.44-5.46. Releases and exposures were calculated using the same methods and assumptions provided in SEIS Subsection 5.2.3 and Appendix F, but with the higher annual throughputs associated with the Alternative Action.

Tables 5.47 and 5.48 provide estimates of the annual health impacts associated with routine and severe accidental radiological releases, respectively. As discussed in SEIS Subsection 5.2.3, the excess risk of incurring a fatal cancer was assumed to be 2.8 cancers per 10,000 person-rem of exposure to a population. The annual occupational excess risk of contracting a fatal cancer from routine operations is about 2.8 in 10,000. The maximum individual excess risk of cancer is 19 in one million (1.9 x 10^{-8}). The excess risk of contracting a fatal cancer to the entire population within 50 miles of the WIPP is 26 in one million (2.6 x 10^{-5}) per year of normal population distributed throughout the total population of 95,810.

It is postulated that accident scenarios discussed in SEIS Subsection 5.2.3 for the proposed action are also appropriate for the Alternative Action. Table 5.48 shows health risks associated with radiation exposures during postulated accidents in comparison to those in the FEIS. Occupational workers will incur an estimated 26 in 10,000 (2.6 x 10^{-3}) excess risk of contracting a fatal cancer.

TABLE 5.44 Alternative Action routine radionuclide releases to the WIPP environment (total activity in Curies/year)

	Test Phase[a]		Disposal Phase[b]		Alternative Action[c]	
Isotope	WHB[d]	SE[e]	WHB	SE	WHB	SE
Co-60	---[f]	---	7.4×10^{-12}	3.5×10^{-5}	7.4×10^{-12}	3.5×10^{-5}
Sr-90	---	---	2.2×10^{-10}	1.0×10^{-3}	2.2×10^{-10}	1.0×10^{-3}
Ru-106	---	---	1.5×10^{-12}	7.2×10^{-6}	1.5×10^{-12}	7.2×10^{-6}
Sb-125	---	---	4.8×10^{-14}	2.3×10^{-7}	4.8×10^{-14}	2.3×10^{-7}
Cs-137	---	---	1.9×10^{-10}	8.8×10^{-4}	1.9×10^{-10}	8.8×10^{-4}
Ce-144	---	---	1.5×10^{-11}	6.9×10^{-5}	1.5×10^{-11}	6.9×10^{-5}
Th-232	7.5×10^{-18}	3.5×10^{-11}	1.7×10^{-17}	8.0×10^{-11}	1.9×10^{-17}	8.8×10^{-11}
U-233	3.4×10^{-13}	1.6×10^{-6}	8.0×10^{-13}	3.8×10^{-6}	8.8×10^{-13}	4.2×10^{-6}
U-235	7.1×10^{-16}	3.3×10^{-9}	1.2×10^{-13}	5.7×10^{-7}	1.2×10^{-13}	5.7×10^{-7}
U-238	1.0×10^{-16}	4.9×10^{-10}	1.0×10^{-14}	4.8×10^{-8}	1.0×10^{-14}	4.8×10^{-8}
Np-237	3.4×10^{-16}	1.6×10^{-9}	7.6×10^{-16}	3.6×10^{-9}	8.5×10^{-16}	4.0×10^{-9}
Pu-238	2.8×10^{-11}	1.3×10^{-4}	1.0×10^{-10}	4.8×10^{-4}	1.1×10^{-10}	5.1×10^{-4}
Pu-239	2.5×10^{-11}	1.2×10^{-4}	1.0×10^{-10}	4.8×10^{-4}	1.1×10^{-10}	5.0×10^{-4}
Pu-240	7.4×10^{-12}	3.5×10^{-5}	3.1×10^{-11}	1.5×10^{-4}	3.3×10^{-11}	1.6×10^{-4}
Pu-241	6.6×10^{-10}	3.1×10^{-3}	2.0×10^{-9}	9.4×10^{-3}	2.1×10^{-9}	1.0×10^{-2}
Pu-242	1.4×10^{-15}	6.7×10^{-9}	5.7×10^{-15}	2.7×10^{-8}	6.1×10^{-15}	2.9×10^{-8}
Am-241	3.7×10^{-11}	1.8×10^{-4}	8.8×10^{-11}	4.2×10^{-4}	9.8×10^{-11}	4.6×10^{-4}
Cm-244	1.1×10^{-13}	5.1×10^{-7}	1.3×10^{-12}	6.2×10^{-6}	1.4×10^{-12}	6.4×10^{-6}
Cf-252	2.7×10^{-14}	1.2×10^{-7}	1.9×10^{-12}	8.8×10^{-6}	1.9×10^{-12}	8.8×10^{-6}
Total	7.6×10^{-10}	3.6×10^{-3}	2.8×10^{-9}	1.3×10^{-2}	2.9×10^{-9}	1.4×10^{-2}

[a] Based on annual throughput equivalent to about 22,000 CH drums.

[b] Based on annual throughput equivalent to about 49,500 CH drums and 400 RH canisters.

[c] Based on annual throughput equivalent to about 55,000 CH drums and 400 RH canisters.

[d] WHB = Waste Handling Building.

[e] SE = Storage exhaust.

[f] Blanks = Isotope not present during Test Phase.

5	5-102	Table 5.45	Heading over Test Phase and Disposal Phase should read "Proposed Action."

Activity	Test Phase	Disposal Phase	Alternative Action
Population[a] (person-rem)	2.7×10^{-2}	8.9×10^{-2}	9.4×10^{-2}
Population background (total person-rem)	$9.6 \times 10^{+3}$	$9.6 \times 10^{+3}$	$9.6 \times 10^{+3}$
Maximum[b] individual (rem)	1.9×10^{-5}	6.3×10^{-5}	6.7×10^{-5}
Individual[c] background (rem)	1.0×10^{-1}	1.0×10^{-1}	1.0×10^{-1}

[a] 50-year committed effective dose equivalent to population within 50 miles.
[b] 50-year committed effective dose equivalent at point of maximum air concentration.
[c] Exposure due to background radiation.

TABLE 5.46 Annual occupational radiation exposure from Alternative Action routine operations (person-rem/year)[a]

	Proposed Action		
Activity	Test Phase	Disposal Phase	Alternative Action
Direct Radiation	7.9	17.9	19.8
Inhalation of Airborne Contaminants[b]	0.29	0.87	0.93
Total	8.19	18.77	20.73

[a] Exposures are total exposures to the entire waste handling crew.
[b] 50-year committed effective dose equivalent for one year of exposure.

TABLE 5.47 Human health risks associated with routine radiological releases for the Alternative Action[a,b,c]

Occupational Risk

	Proposed Action		
Activity	Test Phase	Disposal Phase	Alternative Action
Facility operations	2.3×10^{-3}	5.3×10^{-3}	5.8×10^{-3}
Waste retrieval	2.3×10^{-3}	-----	-----
Current risk of fatal cancers	2.2×10^{-1}	2.2×10^{-1}	2.2×10^{-1}

5 5-103 Table 5.47 Second half of table, "Total Population Proposed Action[c]" should read "Total Population Proposed Action."

Activity	Test Phase	Disposal Phase	Alternative Action
Facility operations	7.6×10^{-6}	2.5×10^{-5}	2.6×10^{-5}
Waste retrieval	7.6×10^{-6}	—	—
Current risk of fatal cancers	2.2×10^{-1}	2.2×10^{-1}	2.2×10^{-1}

[a] Health risks are expressed as the number of excess fatal cancers estimated in the exposed population as a result of annual WIPP-related activities.

[b] Risk of contracting fatal cancer: 2.8×10^{-4} fatalities/person-rem for each year of operation (BEIR, 1980).

[c] Annual health effects risk estimates for genetic effects would be somewhat less (a factor of 0.918) than the numbers presented for cancer fatality risks.

TABLE 5.45 Annual radiation exposure to the public from Alternative Action routine operations

Activity	Test Phase	Disposal Phase	Alternative Action
Population[a] (person-rem)	2.7×10^{-2}	8.9×10^{-2}	9.4×10^{-2}
Population background (total person-rem)	$9.6 \times 10^{+3}$	$9.6 \times 10^{+3}$	$9.6 \times 10^{+3}$
Maximum[b] individual (rem)	1.9×10^{-5}	6.3×10^{-5}	6.7×10^{-5}
Individual[c] background (rem)	1.0×10^{-1}	1.0×10^{-1}	1.0×10^{-1}

[a] 50-year committed effective dose equivalent to population within 50 miles.
[b] 50-year committed effective dose equivalent at point of maximum air concentration.
[c] Exposure due to background radiation.

TABLE 5.46 Annual occupational radiation exposure from Alternative Action routine operations (person-rem/year)[a]

	Proposed Action		
Activity	Test Phase	Disposal Phase	Alternative Action
Direct Radiation	7.9	17.9	19.8
Inhalation of Airborne Contaminants[b]	0.29	0.87	0.93
Total	8.19	18.77	20.73

[a] Exposures are total exposures to the entire waste handling crew.
[b] 50-year committed effective dose equivalent for one year of exposure.

TABLE 5.47 Human health risks associated with routine radiological releases for the Alternative Action[a,b,c]

Occupational Risk

Activity	Proposed Action Test Phase	 Disposal Phase	Alternative Action
Facility operations	2.3×10^{-3}	5.3×10^{-3}	5.8×10^{-3}
Waste retrieval	2.3×10^{-3}	-----	-----
Current risk of fatal cancers	2.2×10^{-1}	2.2×10^{-1}	2.2×10^{-1}

Total Population

Activity	Proposed Action[c] Test Phase	 Disposal Phase	Alternative Action
Facility operations	7.6×10^{-6}	2.5×10^{-5}	2.6×10^{-5}
Waste retrieval	7.6×10^{-6}	____	____
Current risk of fatal cancers	2.2×10^{-1}	2.2×10^{-1}	2.2×10^{-1}

[a] Health risks are expressed as the number of excess fatal cancers estimated in the exposed population as a result of annual WIPP-related activities.

[b] Risk of contracting fatal cancer: 2.8×10^{-4} fatalities/person-rem for each year of operation (BEIR, 1980).

[c] Annual health effects risk estimates for genetic effects would be somewhat less (a factor of 0.918) than the numbers presented for cancer fatality risks.

TABLE 5.48 Human health risks associated with severe accidental radiological releases for the Alternative Action[a]

	Occupational Risk[b,c]		
	Proposed Action[d]		
Activity	Test Phase	Disposal Phase	Alternative Action
Facility operations	2.6×10^{-3}	2.6×10^{-3}	2.6×10^{-3}
Waste retrieval	2.6×10^{-3}	--	--
Current risk of fatal cancers	2.2×10^{-1}	2.2×10^{-1}	2.2×10^{-1}

	Maximum Individual[b,c,e]		
	Proposed Action[f]		
Activity	Test Phase	Disposal Phase	Alternative Action
Facility operations	3.1×10^{-4}	3.1×10^{-4}	3.1×10^{-4}
Waste retrieval	3.1×10^{-4}	--	--
Current risk of fatal cancers	2.2×10^{-1}	2.2×10^{-1}	2.2×10^{-1}

[a] Annual health effects risk estimates for genetic effects would be somewhat less (a factor of 0.918) than the numbers presented for cancer fatality risks.

[b] Health risks are expressed as the probability of an individual contracting a fatal cancer during their lifetime as a result of annual WIPP-related activities. Risks are expressed in exponential form; i.e., 1.0×10^{-4} is equivalent to one chance in 10,000.

[c] Risk of contracting fatal cancer: 2.8×10^{-4} fatalities/person-rem for each year of operation (BEIR, 1980).

[d] Draft FSAR, accident C6.

[e] At the site boundary from underground storage exhaust.

[f] Draft FSAR, accident C10.

Health risks associated with the exposures to an individual at the nearest residence following the severest accident is about 3.1 in ten thousand (3.1×10^{-4}). If credit is taken for filtering underground releases by the HEPA filtration, the risk drops by a factor of one million.

5.3.9 Chemical Assessment: Operations

This alternative involves only a limited volume of the waste located in an aboveground research facility at the Idaho National Engineering Laboratory or at another existing DOE facility. The design and operation of this facility would be in compliance with all applicable regulations pertaining to the management of hazardous waste as well as all required DOE Orders for the management of radioactive waste. The risks to human health and the environment from the operation of such a facility is expected to be minimal. If a decision was made to implement this alternative, more detailed analysis of the site-specific impacts will be conducted.

5.4 DECOMMISSIONING AND LONG-TERM PERFORMANCE

This subsection discusses the environmental effects of decommissioning the WIPP and long-term behavior of the WIPP as a repository for the permanent disposal of TRU waste. Calculations of long-term consequences are based on current technologies, social patterns, agriculture, diets, etc., because there is no credible rationale for selecting a likely future among the unknowable possibilities. In effect, the SEIS uses the present era to illustrate a possible future.

5.4.1 Environmental Consequences of Decommissioning

Decommissioning consists of closing the facility, dismantling and removing the above-surface buildings (unless used for other purposes, see SEIS Subsection 2.6), entombing the underground portions of the facility by removing usable equipment, backfilling open tunnels and installing tunnel and shaft seals, and erecting monument markers.

The consequences of decommissioning the WIPP remain much as described in the FEIS (Subsection 9.3.5). The decommissioning effort will be similar to a heavy construction project in that the same types of heavy equipment will be used. The impacts of using such machinery include an increase in nearby noise levels, increased levels of dust, and a temporary increase in local traffic.

There will be a temporary increase in local employment for the decommissioning force. The long-term socioeconomic effect, however, will be a decrease in the size of the work force once the decommissioning is complete.

The major resources to be expended in decommissioning will be water for decontamination and salt, bentonite, and possibly other materials for the backfilling operations. Fuels and electricity will also be consumed.

Decommissioning activities will be performed under controls that will ensure the safety of the general public and workers. Because decommissioning involves the disposal of contaminated equipment, it will potentially expose workers to radiation. Temporary shielding and extensive decontamination will reduce the exposures of workers. The special procedures taken to protect the work force will also ensure that the more distant general public will be much less exposed.

5.4.2 Post-Operational Performance

5.4.2.1 Changes from the FEIS. The FEIS examined five scenarios for the release of radionuclides to the environment (FEIS Subsection 9.7.1). Those scenarios involved hydraulic interconnections created by borehole drilling or other openings into or through the repository. At that time, it was believed that reasonably expected natural events would result in no release of radioactivity. Since then the understanding of two factors important in undisturbed performance has changed: the rate of gas generation and the source and quantity of brine inflow.

First, gas generated by the waste and the surrounding container material was not thought to be important because the gas permeability was thought to be sufficiently high to allow dissipation. The FEIS states:

> These modes [of gas dispersion] have been tested by mathematical calculation using experimental values for gas permeability. Experiments show that the gas permeability [of the surrounding Salado salt], while not zero, is small enough for some accumulation of gas to be possible; the proper representation of the problem requires simultaneous consideration of the mine response with the gas generation. Some of these calculations have been completed. According to initial estimates based on them, there is little possibility of repository failure from overpressurization at gas-generation rates of less than 5 moles per year per drum. Since these conclusions depend on the gas permeability and the mechanical properties of the repository medium, they will be subject to some revision when data are available from actual underground workings (FEIS Subsection 9.7.3.1).

It was thought that any gas generated would permeate into the surrounding Salado salt and not accumulate to the point that it would pressurize the formation detrimentally. Gas and brine permeability data obtained underground since 1980 indicate that the values assumed in the FEIS for gas permeability in undisturbed portions of the Salado are approximately three orders of magnitude too high. The scenarios discussed below treat gas generation as an important driving force.

Similarly, it was thought in 1980 that brine from the surrounding Salado Formation would be of little importance in the release of radioactivity. The attention was on fluid inclusions, which are small quantities of brine within individual grains of salt. It was known that these inclusions move in a thermal field toward regions of higher temperature. According to the FEIS:

> After a short time, less than a year, the temperature field around an assemblage of canisters will have become so uniform that the weak thermal gradient will bring no more inclusions to the canisters during the period of high heat production....
>
> From experimental data, the total volume of fluid drawn to any canister can be estimated crudely; it may lie between 0.1 and 20 liters, with 0.1 liter more likely....
>
> Rigorous verification of these expectations will require further investigations. Brine migration is now being studied in its entirety, both experimentally and theoretically. Current knowledge is sufficient to predict that brine migration will be of little concern in the WIPP repository, because no CH and little RH TRU waste stored there will produce significant thermal gradients (FEIS Subsection 9.7.3.2).

Fluid inclusions are still thought to be a minor source of brine inflow under the low projected thermal gradients in the repository, but experience underground has drawn attention to another source of brine inflow, intergranular brine. This brine was trapped between individual salt grains millions of years ago. Before the WIPP underground shafts and tunnels were mined (and at considerable distances from them still), formation brines were at high pressure, perhaps as high as lithostatic, i.e., under the weight of the overlying rock at 14 to 15 MPa (2060 to 2200 psi). When the shafts and tunnels were excavated, the pressure at their walls dropped to atmospheric pressure, 0.1 MPa (15 psi). A disturbed zone of small cracks formed in the first few meters into the walls of these openings and the intergranular brine moved toward the lower pressures in the excavation. This brine appears today as moist areas on tunnel walls that evaporate quickly into the dry underground air. Moisture builds up in some closed holes, and it would build up to some extent in the WIPP storage rooms when they are closed. Therefore, until more conclusive information is obtained, brine inflow is also a factor that must be considered in scenario evaluation.

The FEIS considered five scenarios for the release of radioactive material from the WIPP repository (FEIS Subsection 9.7.1.2):

1. At some late time after decommissioning, a drill hole connects the Rustler aquifers above the repository with the Bell Canyon aquifer below, allowing water to flow up through the repository into the Rustler aquifers.

2. A pair of drill holes allow water to flow from the Rustler aquifers down through the repository and back up again into the Rustler aquifers.

3. A drill hole connects a stagnant pool in the repository with the Rustler aquifers, allowing migration of radionuclides upward by molecular diffusion.

4. A pair of connections form so large that all the Rustler water is diverted through the repository and back up into the Rustler aquifers. (This scenario was added to the list as a worst possible case; no processes that might form such connections were postulated.)

5. A drill hole intercepts a waste container, bringing radioactive material directly to the surface.

The fifth scenario treated material brought directly to the surface; the others were concerned with water-borne contaminants. Based on current understanding, these five scenarios are not considered to be fully representative of conditions that may affect long-term repository performance at the WIPP. The understanding of the site hydrology has changed, a quantitative analysis was not performed for a brine reservoir scenario, and none of the FEIS scenarios treats an undisturbed repository.

The scenarios presented in this analysis incorporate the following changes.

- The FEIS treated flow in the Rustler aquifer as if it were entirely porous-medium flow. Data taken since 1980 indicate that the flow is a dual-porosity flow, i.e., fracturing in the Culebra aquifer is also important.

- The FEIS evaluated the health effects resulting from discharge of contaminated Rustler water at its (presumed) natural discharge points in salt lakes and the Pecos River 15 to 20 mi to the southwest of the repository. This SEIS considers a much closer release point, a hypothetical stock well about 3 mi (5 km) south of the center of the site.

- Information obtained since the FEIS indicates that there may be a pressurized brine reservoir in the Castile Formation under at least part of the repository (Earth Technology Corporation, 1987). Therefore, release calculations in this SEIS assume that this reservoir is present.

- TRU waste was assumed to dissolve at the same rate as salt in salt-unsaturated brines entering the repository (an unrealistic assumption). In this SEIS, estimated solubility limits for waste radionuclides are used.

- The FEIS did not consider emplacing borehole seals typical of those used in the oil and gas industry, in the intrusion borehole. These emplacements of borehole seals, including a long-term increase in permeability, is considered in the analyses presented herein.

- Marker Bed 139 (MB139), which in areas disturbed by mining exhibits a relatively high permeability, may be a potential pathway past tunnel seals for the release of waste radionuclides if gas pressures build up in the waste panels.

5.4.2.2 Description of Approach and Data Selection. This SEIS evaluates two basic long-term release scenarios. These scenarios and resulting impacts are expected to bound potential impacts that could result from the long-term disposal of TRU wastes at the WIPP. The first scenario (Case I) examines the expected long-term performance of an undisturbed repository. The second scenario (Case II) examines a hypothetical intrusion into the repository by a borehole drilled through the repository into a pressurized brine reservoir below. Variations of Cases I and II are also examined in this subsection. In Cases IB, IIB, IIC, and IID, the flow and transport properties are intentionally degraded (i.e., the flow is made easier), in order to evaluate long-term repository behavior under more severe, less probable conditions. In addition, in Cases IB, IIB, and IID, potential treatments/engineering modifications are postulated (e.g., compaction of the waste) to minimize the impacts of those consequences. Therefore, these scenarios predict the undisturbed and disturbed behavior of the repository, under expected conditions and under more pessimistic assumptions.

These scenarios involve only CH TRU wastes, not RH TRU waste. RH TRU waste differs from CH TRU waste principally in that it contains beta-gamma-emitting fission products (Tables B.2.10, B.2.11, and B.2.12). The longest lived of these fission products are Sr-90 and Cs-137, which have half-lives of 30 yr, and which decay early in the 10,000-yr period of interest in this SEIS. RH TRU wastes will be disposed of by being placed in individual canisters inserted into holes drilled into the walls of the storage rooms. As the rooms close, the drums of CH TRU waste will be crushed, to some extent intermixed, and will remain in some degree of communication throughout the room, but the RH TRU canisters will remain isolated from each other and from the CH TRU rooms. The RH TRU waste canister is a much smaller target; all together these canisters make up only 2 percent of the area of the CH TRU waste disposal rooms. Therefore, an RH canister is much less likely to be encountered by a drill hole. In addition, the consequences if encountered will be less, because much less radioactivity will be available to the Castile brine flowing up the borehole since it will be limited to that single canister. Similarly, intrusion into the CH TRU rooms will not access the RH TRU canisters isolated in their individual holes. For these reasons, the CH waste alone will account for virtually all long-term effects.

The calculations start with the waste disposal rooms closed (and after the 100-yr period of active institutional controls) and assume unchanging physical properties (e.g., seal permeability, waste porosity) thereafter. The base-case scenarios (Cases IA and IIA) use expected, mid-range values for the various input data required. The rationale for these input values and their uncertainties are discussed in SEIS Appendix I, Section I.2.5.

In each case radiation doses to the most exposed individual are calculated. Some exposures are due to contaminated drilling mud and cuttings brought to the surface, while others result from radionuclides carried by groundwater to a hypothetical livestock well approximately 3 mi south of the center of the WIPP site. (The stock well is assumed to be at the nearest point downgradient where water usable by live stock might be found. The water at this well site is too saline for human consumption). The effects at the stock well are quantified based on the maximum radionuclide concentrations that may occur within 10,000 years.

Lead is used as an indicator chemical in evaluating the potential long-term risks associated with the hazardous chemical constituents of TRU waste. The release of chemical constituents of the WIPP waste depends, among other things, on the initial concentration of the chemicals, the processes that may degrade or alter the chemical species present (e.g., biodegradation and radiolysis), the rate at which these processes progress, and the solubilities of the individual chemicals in the brine. Limited information is available on these factors as they relate to the chemical constituents of TRU waste (WEC, 1989). Metals are stable, although the prevalent chemical species may change because of changes in the repository environment. Based on knowledge of the wastes and the processes that generate them, lead is by far the most prevalent metal in the waste. The solubility of lead in brine is not expected to be limited by its initial concentration in the waste. An estimate of a maximum lead solubility can be made based on equilibrium chemistry from the literature as described in SEIS Appendix 1, Section I.14. Information is unavailable to calculate a source term for hazardous organics. However, based on process knowledge, the quantity of these organics is minor. According to Clements and Kudera (1985), concentrations of volatile organic compounds in the headspace of the drums are well below the saturation values for these compounds, indicating that the amount of these compounds in the waste must be limited.

5.4.2.3 Narrative Descriptions of the Release Scenarios. Two versions of Case I have been examined. Each treats the performance of an undisturbed repository. Case IA examines its expected performance; Case IB examines its performance with degraded waste solubility and groundwater flow properties, and with the waste compacted to reduce its porosity.

Case IA. In an undisturbed repository, the waste storage tunnels are expected to close to nearly their final state in 60 to 200 yr after decommissioning (Munson et al., 1989). Only near the end of this time will there be any appreciable resistance from the waste to the closure. The waste is assumed to compact to an estimated average final porosity of 15 to 21 percent (Lappin et al., 1989).

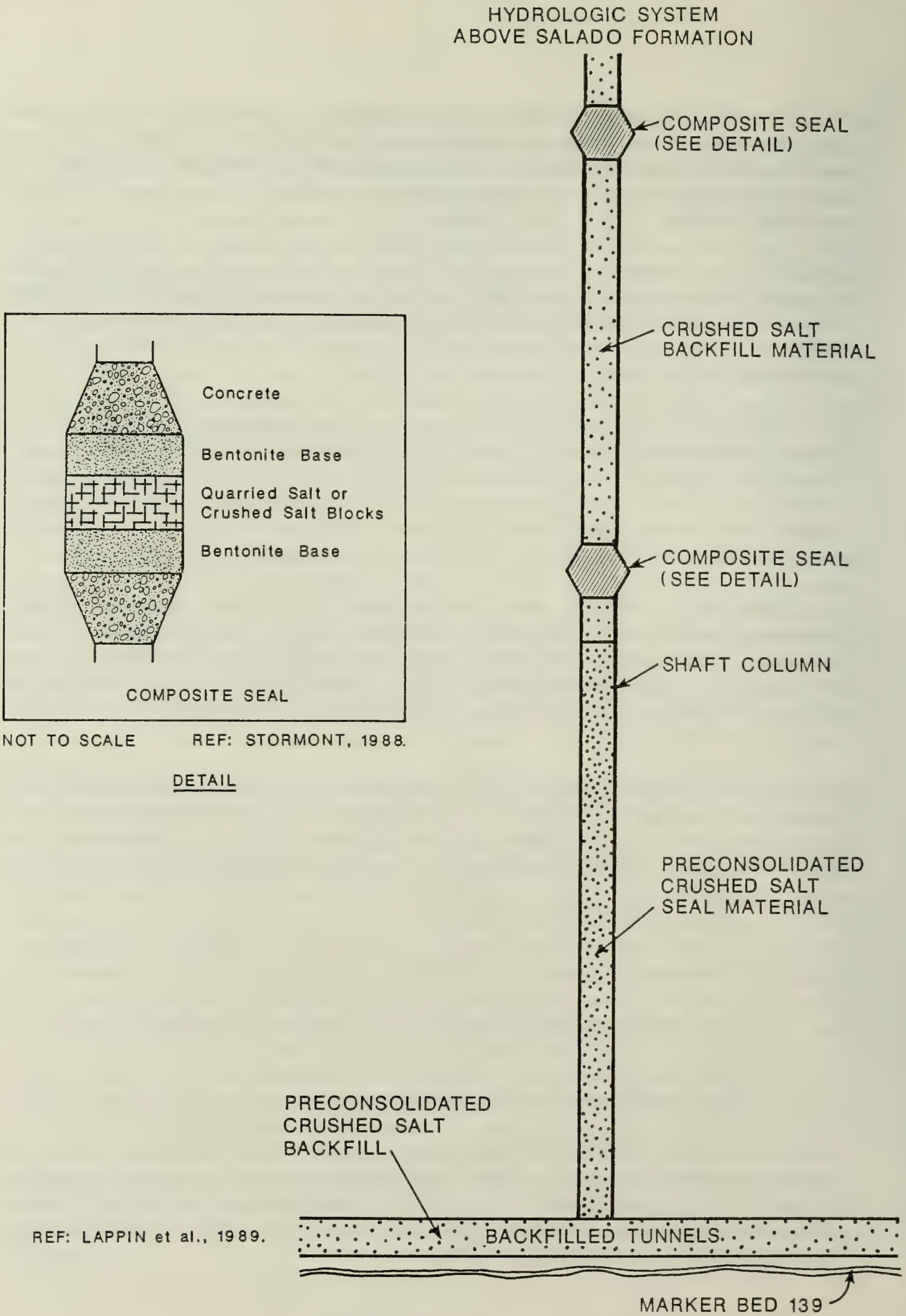
The vertical shaft seals would consist of a salt column interrupted at several points by bentonite-and-concrete plugs (Figure 5.1) (SEIS Subsection 6.3.2.3). The long-term integrity of the shaft seals depends on the lower salt section, which, like the underground tunnels, will be compressed by salt creep to about 95 percent of the salt's original crystal density within about 100 years. The upper salt sections, not being as deep and under less weight of rock, will not close as quickly.

Gas generated by microbial activity and radiolysis in the organic components of the waste and by corrosion of iron in the waste and waste drums is assumed to reach lithostatic pressure shortly after room closure has reached a near final state. Brine will enter the rooms from the surrounding Salado Formation salt until the mounting gas pressure retards the flow. This brine will be trapped in a backfill material consisting of salt and bentonite clay.

Assuming that present estimates of gas generation rates are reasonable, then during the hundred years after the WIPP is decommissioned, gas will be building up in the now closed rooms at a rate faster than it can permeate out into the Salado salt. If the gas cannot escape into the Salado salt, then one or more of the following may occur:

1. Re-expansion of the storage rooms or,
2. Storage of the gas in the disturbed rock zone around the rooms or,
3. Gas movement into Marker Bed 139 with potential for migration up the shaft, or
4. Gas movement either through or past panel seals and then up the shaft.

At least some gas will leave the waste-disposal area of the repository, since the gas pressure cannot build up to the point that it greatly exceeds the pressure caused by the weight of the rock above. Re-expansion is improbable as long as other escape pathways are available. Storage in the more distant parts of the Salado Formation is precluded by the low permeability of that rock.



REF: STORMONT, 1988.

REF: LAPPIN et al., 1989.

FIGURE 5.1
SCHEMATIC OF SHAFT SEAL SYSTEM IN THE SALADO FORMATION

Storage in the disturbed rock zone is possible. This disturbed zone is known to be present, but it is believed to close by salt creep along with the overall room closure. The most probable escape route for gas is through MB139. The MB139 is just a short distance below the floor of the storage rooms, and may become a mechanism for gas to bypass the panel seals. MB139 is a bed of broad extent; it is fractured away from the WIPP underground excavations and has a permeability about ten times greater than that of the Salado Formation. MB139 may allow gas to migrate to the bottom of the shafts, from where the gases may find a pathway upward. If so, that flow will pass other marker beds, into which it will also seep, and may eventually reach the surface. The volumes needed underground to accept all the gas that might be generated and maintain lithostatic pressure in the repository are discussed in Lappin et al., (1989, Section 4.10.2).

Although there is a radioactive gas (radon-222) in the repository, the amount present in the whole repository would be only $2x10^{-4}$ Ci at 5000 years and $1.1x10^{-3}$ Ci at 10,000 years. Moreover its half-life is only 3.8 days. None would remain if waste-generated gas seeps through any leaks that may be present. A slight amount could be released if an intruding drill hole intercepts the repository as analyzed in Case II.

Lappin et al. (1989, Section 4.2), assume that gas will continue to be generated by corrosion for about 500 yr and by bacterial action for about 2000 yr until the iron and cellulosic materials from which they are generated are exhausted. The repository rooms then slowly saturate, and the brine in the waste storage rooms is able to seep out to the base of the shafts and may move upward through the consolidated salt in the shaft seals in response to pore pressure gradients.

The Case IA calculations estimate the rate and magnitude of these liquid-borne releases, assuming instantaneous repository saturation at 2,000 yr and steady state hydrologic pressures and flow rates. The time required for repository saturation may well be thousands of years. The Case I calculations may therefore be conservative, since credit is taken for only 2000 yr of radioactive decay before saturation of the repository.

<u>Case IB</u>. This scenario treats the performance of an undisturbed repository with degraded radionuclide solubility and groundwater flow properties. Case IB differs from Case IA in two respects. First, mitigation measures are assumed in which the waste is compacted to near-solid density. The result of this treatment will be that the storage rooms will have less void space. Therefore, closure to its final state will be earlier and the waste mass will be less porous and less permeable. So little brine will flow into the waste from the surrounding salt that gas generation by corrosion will probably cease or at least occur at a much lower rate. The remaining gas generation, now almost entirely from bacterial action, will be 65 percent lower than in Case IA. Second, in Case IB, some parameters are degraded, including the solubilities of the radionuclides, which are assumed to be 100 times larger, and the resistance to flow in the shaft and panel seals, which is assumed to be a factor of 100 lower. Thus, the contaminated brine will meet less resistance to flow.

Case IB calculations, like those of Case IA, estimate the rate and magnitude of the liquid-borne radionuclide and stable lead releases, also assuming instantaneous saturation and steady-state flow conditions.

Case II. Four versions of Case II have been examined. Each treats the performance of a disturbed repository. Case IIA examines its expected performance; Cases IIB, IIC, and IID incorporate (in various combinations) degraded properties of the stored waste and of the groundwater flow, and waste treatments.

In each case, it was assumed that a drill hole was inadvertently drilled into and through the repository. The likely reason is exploration for oil or gas in underlying strata. Given the precaution taken to mark the site with a permanent monument on decommissioning, this scenario is unlikely; however, its consequences were evaluated.

Assuming current drilling practices, the hole would be drilled by a rotary drill to depth and cased through the Rustler Formation down to the Salado salt. Drilling mud would be used to lubricate the drill bit and remove cuttings, and to prevent any dramatic release of pockets of gas underground.

It was assumed that the repository would be breached at a time when the underground rooms containing the waste have closed to a thickness of about a meter. No credit was taken for radioactive decay before the breach occurred. Some radioactive material would be brought to the surface by the drill mud, and there would be a small release of gases into the drilling mud that contaminates it. These gases would be at lithostatic pressure in the compacted waste (whose porosity is 15 to 21 percent; see SEIS Appendix I.2.1). The drill crew would only be exposed to a very low dose of radiation, because the contaminated gas and cuttings would be well mixed with the drilling mud and diluted, but any individual examining the cuttings would be slightly more exposed. The contaminated cuttings and drill mud would be discharged into a mud pit (a settling pond) where their residue after clean-up would eventually dry and be dispersed by the wind.

Drilling from the repository down to the brine reservoir in the upper Castile Formation (a distance of 270 m or almost 900 ft) would take about 15 hours. During this time the repository waste would be eroded by the circulating drilling mud and additional radioactive material would be brought to the surface and dumped in the mud pit.

The brine reservoir consists of brine at a pressure of 12.7 MPa (1900 psi), somewhat less than lithostatic, and the drilling mud is at hydrostatic pressure for that depth (10 MPa or 1500 psi). The 2.7-MPa pressure difference would tend to drive brine into the drilling mud and to the surface. When the hole reaches the brine reservoir, a pressure pulse would pass up the mud in the drill stem and activate blow-out preventers before the pressurized brine itself could make its way to the surface. The drill crew would increase the drilling mud weight and stop the flow from the brine reservoir.

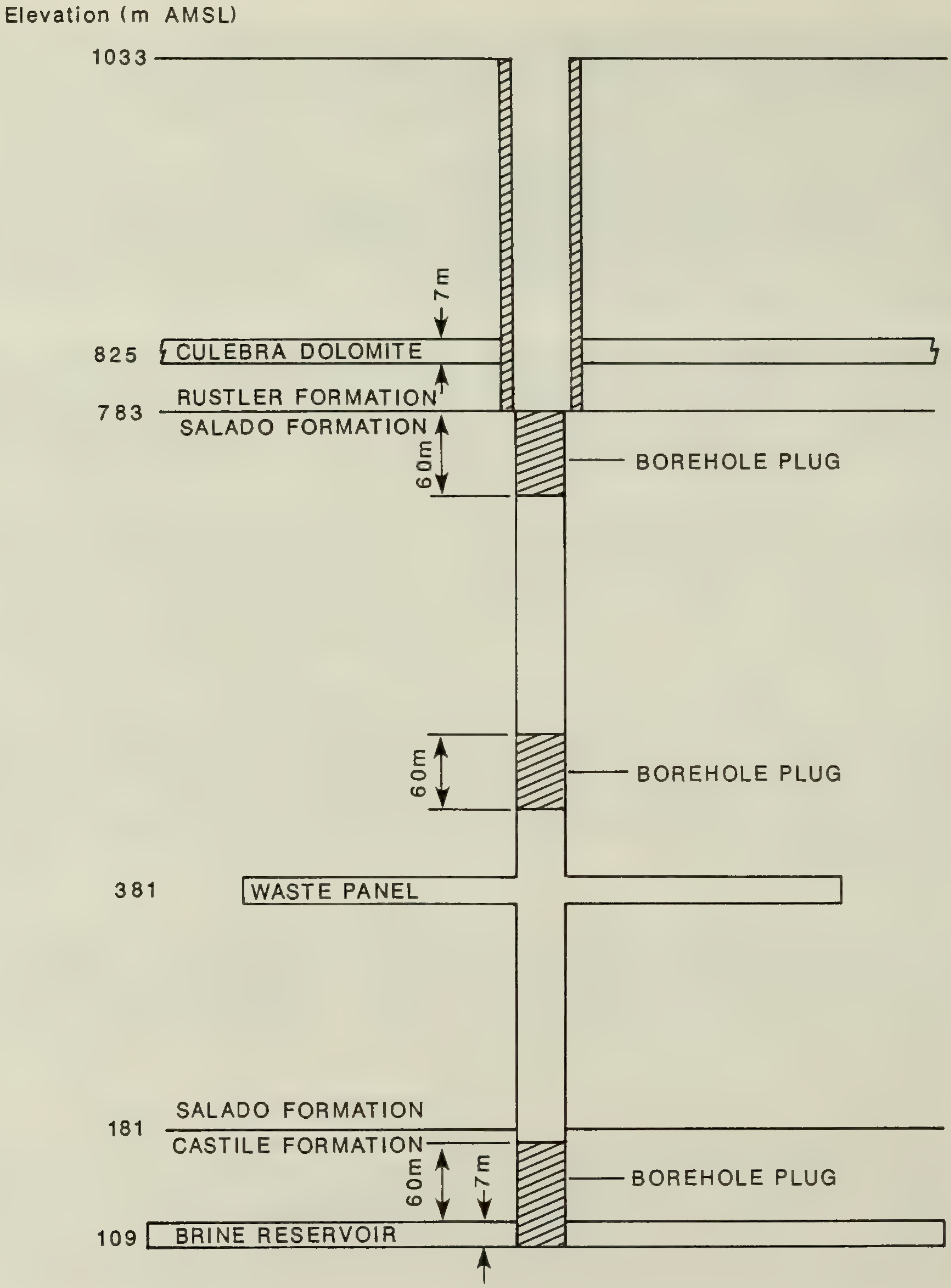
Case IIA. This case assumed that the drill crew would seal off the brine reservoir and drill on to the target depth. Later, when the oil or gas tapped by the hole were exhausted or if the hole proved to be dry, as much casing as possible would be pulled from the hole and the hole would be plugged. The boreholes would have to be plugged according to the regulations of the New Mexico Oil and Gas Commission when abandoned. In southeastern New Mexico these procedures are intended to protect the potash beds from foreign fluids. It was assumed that the boreholes drilled through the repository would be plugged as shown in Figure 5.2.

Industry experience indicates that grout plugs do not maintain good seals for very long (Lappin et al., 1989, Appendix C); Case IIA assumes 75 yr, followed by deterioration to the permeability of a rubble-filled hole in another 75 yr. As these plugs fail, brine would start to flow up through them to the Culebra aquifer in the Rustler Formation, and at the same time a lesser amount down to the Bell Canyon Formation because the Bell Canyon is at a lower hydraulic pressure than the brine reservoir in the Castile. (For this SEIS, however, the flow is conservatively assumed to be upward.) The upward flow would be slow enough, and the waste section permeable enough for the reservoir brine to come to equilibrium with the waste in the repository. The brine would thus become saturated with waste radionuclides and stable lead. In addition, brine inflow from the surrounding Salado Formation salt (1.3 m^3/yr per panel) would be mixed with brine reservoir fluid and move up with it to the Culebra aquifer. The radionuclides and stable lead that get into the Culebra aquifer flow to the south with the Culebra water, but not as fast, because they would be retarded to various degrees by sorption in the rock through which they pass.

Culebra water was assumed to be used off-site to water cattle. A stock well was hypothesized at the closest possible point to the WIPP that might yield usable (stock-potable) water (water with no more than 10,000 mg/l total dissolved solids). This point was estimated to be 3 mi to the south of the center of the WIPP site.

The Case IIA calculations estimate the radiation doses and lead exposures to the individual most exposed to the cuttings brought to the surface by the drill hole. Also estimated were the arrival times and resulting maximum contamination levels (within 10,000 years) at the hypothetical downgradient stock well where some beef cattle would get their drinking water. It was assumed that people would use this beef as their only source of meat and would thereby be exposed to radiation and dissolved lead.

Case IIB. This scenario treated the expected performance of a disturbed repository with degraded radionuclide solubility and groundwater flow properties. Case IIB differs from Case IIA in that the WIPP waste was assumed to be compacted before emplacement to near-solid density. This resulted in a much less porous and less permeable waste mass and a reduced rate of gas generation. The brine passing up the borehole from the Castile reservoir was assumed to pass by the level of the waste room without mixing with its contents. However, brine inflow from the Salado Formation salt would continue. This formation brine would be saturated with waste radionuclides and lead (the former assumed to be a hundred times more soluble than in Case IIA), mixes with the upflowing brine, and also flows up into the Culebra aquifer. There the



REF: LAPPIN et al., 1989.

FIGURE 5.2

REPRESENTATIVE PLAN FOR PLUGGING A BOREHOLE THROUGH THE REPOSITORY TO A CASTILE FORMATION BRINE RESERVOIR matrix porosity was assumed to be 56 percent lower than in Case IIA (7 instead of 16 percent porosity) and the fracture spacing and fracture widths larger by a factor of 3.5 (SEIS Appendix I.2.6). These and other degraded parameters would increase groundwater flow rate in the Culebra. Case IIB takes credit for waste compaction and grouting in eliminating free mixing of Castile brines in the repository, but does not take credit for any reduction of inflow from the Salado Formation.

Case IIB calculations, like those of Case IIA, estimated the maximum radiation doses (within 10,000 years) to the most exposed individual at the ground surface near the drill hole. They also estimated the contamination levels and health effects from material that would enter the food chain from contaminated water drawn from the hypothetical down-gradient stock well for cattle to drink.

Case IIC. This scenario also treated the performance of a disturbed repository, predicting the maximum doses to humans that would occur within 10,000 years. It differs from Case IIB only in that the WIPP waste was not compacted, so that the brine passing up the borehole from the Castile reservoir would be able to reach solution equilibrium with the waste in the repository. Until the radionuclides start to become depleted, the Castile brine reaching the Culebra aquifer is saturated (to 10^{-4} molar) with waste radionuclides.

Case IID. This scenario also treated the performance of a disturbed repository, predicting the maximum doses to humans that would occur within 10,000 years. In it the waste was pretreated as in Case IIB, but it differs in that 1) the solubility of the radionuclides was taken as 10^{-6} molar, as in Case IIA, and 2) the only brine inflow was into the room penetrated, not into an entire panel.

5.4.2.4 Analysis of Scenarios - Initial Conditions.

Tunnel Closure. Closure is the crucial process that must occur in order to provide effective encapsulation of the waste placed in the WIPP. Knowing how quickly a room will close and entomb the waste is essential in determining the performance of these rooms. This process is the result of the creep of the salt, which crushes the waste and backfill mixture into a compact mass.

Prior to mining the excavations underground, it was assumed that the final state of the waste emplaced in the WIPP, in the absence of human intrusion, would be compacted and dry (FEIS Subsection 9.7.3.2). This assumption was based on the best conceptual models and data available at that time.

The observed closure behavior is not simple. It is both more rapid and more complex than expected prior to actual mining. In fact, the total macroscopic closure to date is about 3 times that originally expected. Ignoring possible complications, the more rapid closure results in an estimated time of 60 to 200 yr for closure to the final state.

There are several structural effects or processes due to excavation that were not anticipated in the FEIS. The observed excavation effects result in the formation of a disturbed rock zone near the repository level (Borns and Stormont, 1987). At present, the significantly disturbed zone extends about 10 ft from the underground workings, depending on the size and age of individual tunnels. It has not been possible to include excavation effects in numerical modeling to date, nor is there consensus concerning their importance.

The characteristics of the disturbed rock zone include: 1) a volumetric dilatation or expansion caused by openings between grains, 2) macroscopic fracturing from previous fractures opening and from new ones forming, 3) order of magnitude increases in apparent permeabilities, 4) decreased mechanical strength of the salt; and 5) development of zones of partial saturation.

The existing model of the closure behavior of the formation is at least partially consistent with available data. The model is based on the interpretation that coherent creep (i.e., movement of the rock mass as a whole rather than by the formation of fractures) of the Salado Formation salt will completely dominate the system, independent of any disturbed rock zone that might develop. The model assumes that: 1) any disturbed rock zone is small in volume and importance relative to the volume of the deforming portions of the Salado Formation, and 2) the disturbed rock zone developed during excavation will be healed during the final stages of closure. Mechanical back pressures, especially if the disturbed rock zone has expanded to include the anhydrite marker beds, will not occur until very late in the closure process.

A second level of conceptual complexity, based on underground observation of excavation effects, also assumes that coherent creep of the Salado Formation outside the disturbed rock zone is the major structural process involved in the closure. However, the observed effects suggest that the disturbed rock zone may:

- Serve as a "sink" for some of the brine that seeps into the facility

- Create a larger effective room size, increasing the time required for closure and the volumes available for brine inflow

- Affect the final state of closure by extending to intersect the relatively brittle MB139 or other more permeable units above or below the repository level

- Provide discrete fractures that might be propped open by high gas pressures

- Degrade the expected post-emplacement performance of seals in tunnels and shafts.

It is now also known that there are strong structural members in the waste such as pipes and rods. This raises the possibility of less than complete compaction of waste and backfill under lithostatic load.

In summary, the uncertainty concerning the mechanical behavior of the Salado Formation during closure of the WIPP repository does not imply fundamentally different conceptual models. Far-field coherent creep of the Salado Formation salt is still the dominant process involved. The present uncertainty concerns only the time-dependent extent and possible importance of the disturbed rock zone.

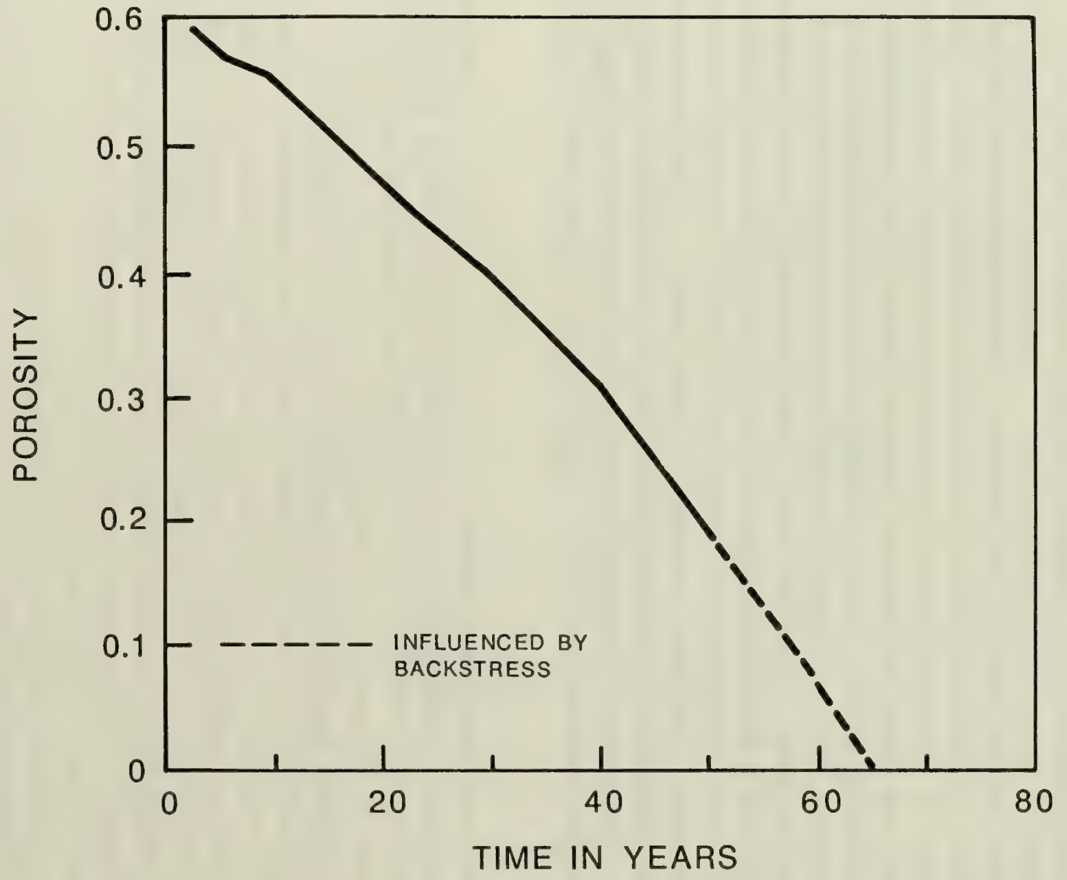
An estimate was made of how rapidly the closure would decrease the porosity of a waste disposal room. The calculated rate of closure of an empty disposal room (Munson et al., 1989) was used to determine the volume of empty space (voids) at a given time. The void volume was obtained by subtracting the volumes of the solids in the waste, the solids in the backfill, and the volume of brine flowing into the room (as a function of time; from Nowak et al., 1988) from the room volume.

An assumption in using empty room closure data for this estimate was that any backstress by the room contents would be insufficient to retard the closure. This assumption appears to be warranted because finite-element calculations show that backstress is significant only during the very last stages of closure. The no-backstress assumption is also consistent with the current model for compaction of the waste, which assumes that the final void volume depends only on the stress applied to the waste, and not the stress history; that is, the only effect of backstress is to prolong the time required to achieve the final compacted state. Estimates using these assumptions show that the final void volume will be achieved in about 60 yr, and the amount of brine inflowing into the room during that time will be of the order of 6 to 37 m^3 (Nowak et al., 1988; Lappin et al., 1989, Section 4.3.1), far less than would be required to saturate the total of 106 m^3 of void volume. Figure 5.3 shows the results of these calculations of room closure. All of this brine can be sorbed by the bentonite in the backfill (Lappin et al., 1989, Section 4.8.1).

The permeability of the room contents is needed, at least roughly, so that the ability of brine to flow through it can be estimated. This permeability is influenced by the large difference in estimated hydraulic conductivity for the three waste categories of sludge, combustibles, and metals and glasses. The computation of a net hydraulic conductivity depends on whether the brine flows through it by paths that are in parallel or in series: the sludge conductivity dominates the series path case with an estimated average conductivity of 4×10^{-9} m/s, and the metal waste conductivity dominates the parallel paths case with an estimated average conductivity of 4×10^{-6} m/s (Lappin et al., 1989, Section 4.8.2). It is unlikely that convincing arguments can be made that the waste is distributed uniformly enough within the room to presume parallel flow processes; however, flow in parallel is conservatively implied by assuming a net hydraulic conductivity to the room content in the order of 10^{-6} m/s.

The net conclusions of these studies are :

- The rooms will reach full closure in 60 to 200 yr
- The final room porosity will range from 15 to 21 percent
- Marker Bed 139 will not be healed by closure.



NOTE: THE BACKFILL IS ASSUMED TO BE 70% SALT, 30% BENTONITE WITH AN INITIAL DENSITY OF 1300 Kg/M^3.

REF: LAPPIN et al., 1989.

FIGURE 5.3
VOID REDUCTION DURING ROOM CLOSURE

Seal Compaction. Tunnel seals will be emplaced at the entrances to each of the eight waste storage panels, in the main access ways at the head of the first four panels and on the shaft side of the access ways of all eight panels (SEIS Figure 6.1) The purpose of these seals will be to isolate the panels from each other and from the shafts to the surface. Shaft seals will also be emplaced (SEIS Subsection 6.3.2.3).

The tunnel seals will consist of preconsolidated crushed salt, possibly in the form o salt blocks. This salt will be held in place by end caps. These end caps are no expected to maintain their integrity in the long-term; they serve only as a short-term barrier to keep the salt in place until tunnel closure consolidates it to its final densit (Stormont, 1988).

Model calculations have shown that crushed salt offers little resistance to creep closure until it has reconsolidated to 95 percent of the density of intact WIPP salt (Sjaardema and Krieg, 1987). Therefore, assuming no retardation of room closure, crushed salt backfill in the underground drifts is expected to reconsolidate in about 100 years to 0.95 relative density. Laboratory tests have shown that the permeability of reconsolidated crushed salt decreases montonically with increasing relative density and reached a permeability of 1×10^{-20} m^2 at 0.94 relative density (Holcomb and Shields, 1987).

Only small-scale seal performance tests have been conducted in situ at the WIPP (Peterson et al., 1987). These tests yielded an average effective permeability of 4×10^{-19} m^2 and a porosity of 0.03. However, uncertainty still remains on the long-term performance of full-scale seals. Therefore, in an attempt to bound this uncertainty, a MB139 seal permeability of 4×10^{-17} m^2 was used for calculations in the degraded Case IB. During the Test Phase, large-scale seal performance tests will be conducted to reduce this uncertainty associated with long-term seal permeability.

Brine Inflow. The FEIS recognized that the WIPP salt is not completely dry (FEIS Subsection 9.7.3.2). Water was assumed present only in fluid inclusions within individual grains and in hydrous minerals. The FEIS principally treated brine that migrates toward heat sources. Bedded salt is not pure on a macroscopic scale. It is now realized that intergranular brine plays a primary role, as well as water in other materials such as clays, and that this brine will move toward the lower pressure of the open waste disposal rooms.

A model has been developed for predicting the movement of brine into the WIPP excavations from the surrounding rock salt (Nowak et al., 1988). This model is based on Darcy flow (flow according to Darcy's Law), a well-known and accepted way of describing groundwater movement in granular deposits. The values used for model parameters are consistent with independent measurements of brine and host rock properties, and the brine movements calculated with the model are consistent with data on brine accumulations in test boreholes over periods of 2 to 3 yr.

The capacity of the host rock salt to allow fluid flow through it under the driving force of pressure gradients, known as the "permeability," is very small at the WIPP, in the range of 1 to 10 nanodarcies (10^{-21} to 10^{-20} m^2). This range of permeabilities agrees well with in situ fluid flow measurements (Nowak et al., 1988).

Darcy flow in geologic materials is well understood, and the mathematical formalism describing it is accepted by the scientific community. In Darcy flow, fluid flows in the direction of lower pressure by relationships including the effects of permeability, fluid viscosity, and the elastic properties of the solid and fluid. For some circumstances, the solution to the diffusion equation can be written out explicitly, being directly analogous to the diffusion of heat through solids.

The use of the present Darcy-flow model for estimating brine inflow at the WIPP involves several assumptions:

- A network of interconnected pores exists in the surrounding salt that extends outward without bound.
- Brine pressures in the formation beyond the disturbed rock zone are lithostatic. The pressure cannot rise above that implied by the weight of the rock above it. The use of lithostatic pressure, rather than something between that and hydrostatic, provides an effective upper bound on the inflow.
- Brine flow is radially symmetric (two-dimensional). The effect of three-dimensional features, such as the ends of rooms, is to strengthen the flow there, because the ends draw in brine from a greater volume of the formation.
- Backstress from the room contents is negligible until near the end of the closure.

Prediction of brine inflow cannot be undertaken without the use of physical models, due to the limitations of the small scale tests that have been performed to date. For example, measurements made in boreholes of the same small size reveal little about the brine inflow to large excavations. Furthermore, only models can be used to extrapolate from tests done on a short time scale to much longer periods of time. A model is necessary to translate the brine flow pattern around a test borehole and its change with time to the brine flow pattern and time history surrounding a waste disposal room.

A series of analytical brine-inflow calculations have been made using geometries that approximate the WIPP configuration (Nowak et al., 1988). Their results are given in Table 5.49. The figures tabulated are for a period of 200 yr, assuming no resistance to inflow during that period. In actuality, the room walls will have closed in on the waste in half that time and gas generated by the waste may have built up to lithostatic pressure, stopping the inflow. The lateral, semi-infinite entry in Table 5.49 (line a) considers a rectangular-cross-section tunnel in a layered medium such that brine inflow cannot come from above or below, but must come from either side. The lateral finite entry (line b) considers inflow to one room among an array of similar rooms separated by pillars of finite width. In this case, brine can only be drawn from the volume of salt half the distance to the next room. The radial entry (line c) considers inflow to an isolated tunnel (assumed round for ease of calculation) from all the space around it.

The line-sink entry (line d) considers the inflow into a round tunnel at longer times, when the inflow has approached a steady-state. This fourth calculation yields a smaller brine inflow than the third, because the rapidly changing rate of flow at early times after excavation is not included.

The largest of these volumes is 40.6 m^3 in 200 yr. Because that figure is only 1.2 percent of the initial room volume, it would appear that brine inflow will have little effect on room closure. A more exact numerical calculation of inflow into a rectangular cross-section room (4 x 9 m) in an array of similar rooms yields an inflow of 43 m^3 (Nowak et al., 1988) in 100 yr.

TABLE 5.49 Cumulative volume of inflow at 200 yr (m^3) for two values of permeability (k)

Model	$k=10^{-21}$	$k=10^{-20}$
Lateral semi-infinite[a]	0.7	2.3
Lateral finite[b]	0.4	0.4
Radial[c]	6.7	40.6
Line sink[d]	2.6	26.3

[a] Isolated tunnel with flow confined between upper and lower strata, no adjacent rooms

[b] Same as [a], but with other rooms nearby

[c] Radial flow to an isolated tunnel

[d] Steady-state flow to an isolated tunnel

Brine sorption may be an important function of backfill. The addition of bentonite to crushed salt is being examined for its ability to sorb water. The focus is on a mixture of 70 percent crushed salt and 30 percent bentonite. The current estimate is that in each room between 40 and 80 m^3 of brine can be sorbed by this salt-bentonite mixture without degrading its physical integrity in the compacted state (Lappin et al., 1989, Section 4.8.1). The 40 m^3 figure comes from the amount of chemical absorption that produces a swelling pressure equal to lithostatic. The 80 m^3 figure comes from the amount of water than can be added to the bentonite-salt mixture without degrading the mixture's permeability. Neither figure takes credit for the sorptive capacity of the salt in the mixture or of the waste.

Potential for the formation of a slurry. It has been suggested that free brine in the waste storage areas can entrain particulates, forming a "slurry" (Chaturvedi et al., 1988; National Research Council, 1988). It can be inferred from the rates of fluid flow in the Case IIB borehole (3.2×10^{-6} m^3/s, see Table 5.56) and the diameter of the borehole (0.334 m, see Table 5.58), that the velocity of flow in this borehole is about 4×10^{-5} m/s. Only a very small particle (i.e., colloids) could be entrained in such a low-velocity flow. The formation of colloids is allowed for in the range of solubilities used in the SEIS calculations. Consequently, the slurry hypothesis is not considered credible and is not included in the calculation of impacts herein.

Two-phase fluid flow. This phrase could refer to three processes: 1) a gas cap forms on the Castile brine reservoir that increases the borehole brine flow, 2) inflow from the Salado Formation rock that is accompanied by gas that was in solution in that brine, and 3) phenomena within the residual porosity in the waste disposal rooms that is only partly filled with liquid.

In the first instance, the gas cap will only develop as the intruding borehole relieves pressure on the brine and lets gas come out of solution. The increased flow caused by this gas would decrease radionuclide concentration input to the Culebra in Cases IIB and IID because the same amount of Salado Formation brine would be diluted in a greater quantity of borehole brine. In cases IIA and IIC, the total amount of liquid injected into the Culebra would increase, but contaminant concentrations would remain the same.

In the second instance, the evolution of gas from the Salado Formation brine will help that brine to flow into the waste storage rooms. In all four variants of Case II, this will tend to increase the brine inflow and hence the concentrations input into the Culebra. On the other hand, the assumption of Darcy flow may already have overestimated the rate of brine inflow.

In the third instance, with gas and brine both occupying the residual 15 to 21 percent open space in the waste disposal rooms, the backpressure of the gas phase will tend to reduce the amount of brine inflow from the Salado Formation. This effect tends to counteract the effect of having two fluids present in the host rock.

Two-phase flow and transport are not treated quantitatively in this SEIS because of code limitations. One of the purposes of the Test Phase is to investigate the implications of two-phase flow.

Gas generation. The gas and water contents of the disposal rooms will affect the long-term performance of the repository, especially in the event of human intrusion. Chemical reactions can produce or consume large amounts of gas and water. The air trapped in the disposal rooms at the time they are filled and sealed will consist mostly of nitrogen and oxygen. The Salado Formation will release brine and gas, primarily nitrogen, the oxygen originally trapped in the formation having been used up in various oxidation reactions. Microbial activity will oxidize cellulosic and other materials in the waste and will produce carbon dioxide (CO_2) as well as other gases, including hydrogen sulfide (H_2S), methane (CH_4), and nitrogen. The net effect of microbial activity on the amount of water in the repository, however, is unclear; drum corrosion can either consume quantities of water or, in the case of anoxic (oxygen-poor) corrosion, produce hydrogen. Microbial consumption might remove hydrogen (H_2) during sulfate (SO_4^{-2}) reduction. H_2S may be removed by reaction with the iron of drums or iron corrosion products to form pyrite (FeS_2). The formation of FeS_2, however, will release the H_2 consumed during the sulfate reduction. Radiolysis of brine, cellulose, plastic, and rubber waste products will consume water and produce carbon monoxide, carbon dioxide, hydrogen, and oxygen.

These reactions are discussed in detail by Lappin et al. (1989, Appendix A). The best available review of laboratory data was used for the 1980 FEIS (Subsection 9.7.3.1; Molecke, 1979). This estimate considered four processes: bacterial degradation (the most important process), chemical corrosion, radiolysis, and thermal degradation.

The National Academy of Sciences reviewed these estimates (National Research Council Panel on the WIPP, 1984), and accepted Molecke's (1979) "most probable average" estimate of 0.85 moles of gas generated per drum per yr by bacterial action. This SEIS assumes that this "best estimate" continues until 606 moles of gas per drum are produced; this takes 710 yr.

In the presence of water, the waste drums can corrode to produce hydrogen by the oxidation reaction involved in rust:

$$3H_2O + 2Fe^{-3} > Fe_2O_3 + 3H_2.$$

Data reviewed by Molecke (1979) produced an estimate of the rate of production of hydrogen by corrosion of 2 moles of H_2 per drum per year for 336 year (total of 672 moles). Lappin et al. (1989), Section 4.2.3; Appendix A extrapolated data from Haberman and Frydrych (1988) at considerably higher temperatures than expected in the WIPP to produce a much smaller estimate of 0.262 moles per drum per year for 2,000 years (total of 524 moles). This SEIS uses an average figure for corrosion-produced gas of 1.13 moles per drum per yr to produce 596 moles during a period of 527 yr.

In addition, the WIPP waste is projected to contain considerable quantities of metals, mostly iron. Using an estimate of 29.2 kg of iron per drum and 14.6 kg of iron in the waste in each drum, Lappin et al. (1989) implied that the hydrogen generation potential should be increased by 50 percent or 0.57 moles per drum per year for a total of 1.70 moles per drum per year of corrosion-produced gas and a total gas production of 894 moles per drum.

Radiolysis and thermal degradation are small contributors by comparison. Estimates of their magnitudes are less than 0.05 and from 0.02 to 0.2 moles per drum per yr (FEIS Subsection 9.7.3.1).

This SEIS uses a gas generation rate of 0.85 moles per drum per yr from microbial degradation of organic materials in the waste (Molecke, 1979) resulting in a total amount of gas generated by bacterial action of 606 moles per drum. When the repository becomes saturated with brine, gas will also be produced by the corrosion (rust) of the steel drums and their iron-bearing contents. This process will generate 1.70 moles per drum per yr of hydrogen, and a total amount of gas produced by corrosion of 894 moles per drum (Lappin et al, 1989). These two processes combine to result in a gas generation rate of 0.85 + 1.70 = 2.55 moles per drum per yr and a total gas production of 606 + 894 = 1500 moles per drum.

The period over which the repository behavior will be dominated by gas generation is uncertain because of uncertainties in gas-generation potentials and gas-generation rates. This period could extend to 10,000 yr or beyond. The estimated rates and total generation potentials, although uncertain, were used when needed for calculations. Better definition of gas generation under a range of possible repository conditions is a major reason for emplacement of CH TRU waste during the WIPP Test Phase, in addition to laboratory-scale and bin-scale experimentation.

Radionuclide Concentrations in Brines. Recently an attempt has been made to estimate the solubilities of certain of the transuranic elements in WIPP brines under the conditions expected for the WIPP disposal rooms. A detailed description of this exercise appears in Lappin et al. (1989, Section 4.5).

Two standard brines were defined, one representing intergranular brine from the Salado Formation and one representing fluid from a brine reservoir in the Castile Formation. However, no thermodynamic data (solubility products for solid phases or stability constants for dissolved organic or inorganic complexes) were found in the literature for these elements (Am, Np, Pu, U, and Th) in solutions with ionic strengths (I) as high as those of the standard Salado and Castile brines (I = 7.66 and 6.14 M (molar), respectively); most existing data apply to solutions with I no greater than 1 M. Furthermore, most of the data are for simple metallic complexes; there are very few data for the complexes that will probably be important in these brines.

An attempt was made to estimate thermodynamic data for these elements by: 1) extrapolating existing data to the ionic strengths of the WIPP brines, 2) using the data directly for the WIPP brines or arbitrarily changing them, and 3) extrapolating data for chemically analogous complexes. Unfortunately, these procedures result in order-of-magnitude uncertainties. In addition, influences of other processes are not yet accounted for, including microbial activity, anoxic corrosion, and the sorption of radionuclides by bentonite and iron oxides.

Laboratory experiments in the WIPP Test Phase will provide data on the solubilities and sorption of radionuclides under expected repository conditions. In lieu of such data, this SEIS uses an estimate of 10^{-6} M for the solubilities of Pu and Am, the important TRU elements in TRU waste. This is an intermediate value on a logarithmic scale of the range of values of dissolved radionuclide concentrations (10^{-3} to 10^{-9} M) that, based on solubilities in fresh water and weaker brines, have been used for sensitivity studies involving the source term.

TABLE 5.50 Description of and input parameters for cases analyzed

Case	Description	Repository Parameters	Transport Parameter
IA	Undisturbed Performance	EXPECTED Radionuclide Solubility 10^{-6} m Lead Solubility in brine -116mg/l	EXPECTED Lower Shaft Permeability 10^{-20} m^2 Marker bed 139 seal permeability $4 \times 10^{-19} m^2$ Culebra permeability 5×10^{-15} to 5×10^{-13} m^2 Culebra matrix porosity 0.16
IB	Undisturbed Performance	DEGRADED Radionuclide Solubility 10^{-4} m Lead Solubility in brine -116mg/l	DEGRADED Lower shaft permeability $10^{-18} m^2$ Marker Bed 139 seal permeability 4×10^{-17} m^2 Culebra permeability 5×10^{-15} to 5×10^{-13} m^2 Culebra matrix porosity 0.07
IIA	Response to Breach of Castile Brine Reservoir	EXPECTED Radionuclide solubility 10^{-6} m Lead solubility in brine 116 mg/l Lead solubility in Culebra 54 mg/l Waste/backfill permeability (sufficient for mixing[a]) Salado brine inflow 1.3 m^3/panel/year	EXPECTED Long-term plug permeability 10^{-12} m^2 Culebra matrix porosity 0.16 Culebra fracture porosity 0.0015 Culebra fracture spacing 2 m Culebra free-water diffusivity 1×10^{-6} cm^2/s Culebra K_ds range 01 to 200 mL/g Culebra matrix tortuosity 0.15
IIB	Response to Breach of Castile Brine Reservoir	PERMEABILITY LIMITED SOLUBILITY DEGRADED Radionuclide solubility 10^{-4} m Lead solubility in brine 116 mg/l Lead Solubility in Culebra 54mg/l Waste precompaction reduces permeability (enough to prohibit mixing[b]) Salado brine inflow 1.3 m^3/panel/year	DEGRADED Long-term plug permeability 10^{-11} m^2 Culebra matrix porosity 0.07 Culebra fracture porosity 0.0015 Culebra fracture spacing 7 m Culebra free-water diffusivity 5×10^{-7} cm^2/s Culebra K_ds range 0.05 to 100 mL/g Culebra matrix tortuosity 0.03

TABLE 5.50 C[illegible]ded

Case	Description	Repository Parameters	Transport Parameter
IIC	Response to Breach of Castile Brine Reservoir	DEGRADED Radionuclide solubility 10^{-4} m Waste/backfill permeability sufficient for mixing[a] Salado brine inflow 1.3 m^3/panel/year	DEGRADED Long-term plug permeability 10^{-11} m^2 Culebra matrix porosity 0.07 Culebra fracture porosity 0.0015 Culebra fracture spacing 7 m Culebra free-water diffusivity 5×10^{-7} cm^2/s Culebra K_ds range 0.05 to 100 mL/g Culebra matrix tortuosity 0.03
IID	Response to Breach of Castile Brine Reservoir	PERMEABILITY LIMITED SOLUBILITY AS EXPECTED Radionuclide solubility 10^{-6} m Waste/backfill permeability prohibits mixing[b] Salado brine inflow 0.1 m^3/room/year	DEGRADED Long-term plug permeability 10^{-11} m^2 Culebra matrix porosity 0.07 Culebra fracture porosity 0.0015 Culebra fracture spacing 7 m Culebra free-water diffusivity 5×10^{-7} cm^2/s Culebra K_ds range 0.05 to 100 mL/g Culebra matrix tortuosity 0.03

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[a] Sufficient for mixing = it is assumed that Castile brine equilibrate to same radionuclide and lead concentration as in repository at each time step.

[b] Because of elimination of brine mixing, only long-term source of radionuclides and lead is from Salado brine flow through waste/backfill.

5.4.2.5 Analysis of Scenarios: Cases IA and IB. Table 5.50 briefly describes the conditions and input parameters for the cases that have been modeled. This table is provided to aid understanding of the detailed discussion that follows.

Cases IA and IB examine the expected performance of the repository when it is left undisturbed. These cases analyze the potential for radionuclide and lead migration from the repository through the various tunnels and seals and the surrounding geologic media to the external environment. The system analyzed comprises the wastes in the repository, the engineered barriers, and the surrounding geologic media, including MB139, which lies just under the disposal rooms and access tunnels.

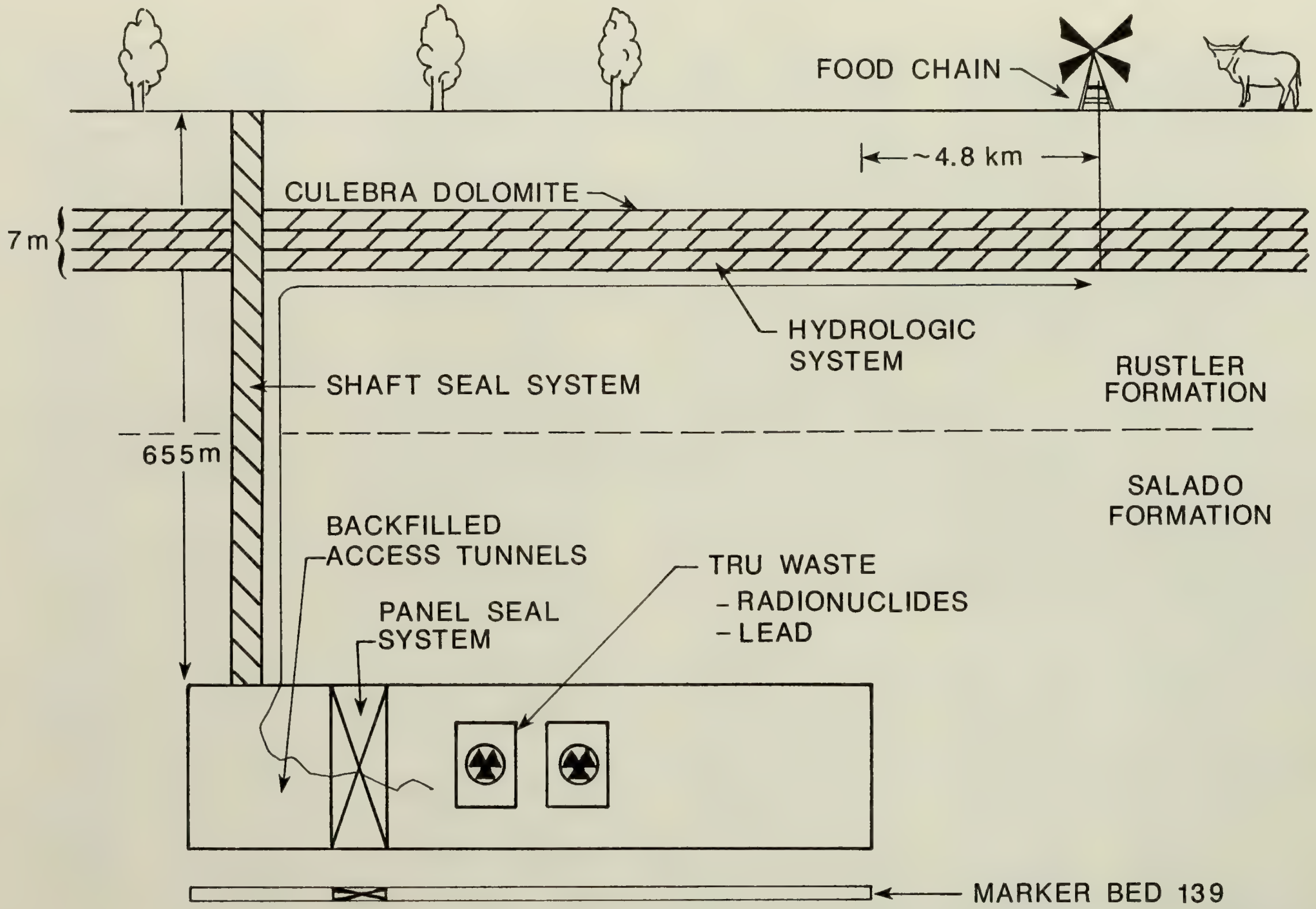
Case I is divided into two parts. Case IA is intended to simulate expected performance using the best available values for input parameters. This simulation represents the most realistic evaluation of expected undisturbed repository behavior without modification of existing designs of engineered barriers or wastes. Case IB is intended to simulate performance under unfavorable and unlikely conditions.

Conceptual model of the system. After the WIPP is decommissioned, the system will consist of rooms filled with waste and backfill, but no free water will be present. New fractures will have started to form in MB139 as a result of earlier excavation of the tunnels and rooms and in response to later salt creep into these excavations. These new MB139 fractures principally occur directly under the excavations, including the Experimental Program area to the north of the access shafts as well as the disposal rooms. Salt-based grout seals will be in place in MB139 directly under the panel seals. Access drifts and the Test Phase area will have been backfilled and shaft seal systems will be in place.

Gas generation in waste materials and drums will begin before the facility is finally closed and will continue after closure (SEIS Subsection 5.4.2.4). Rooms and tunnels will have closed, crushing the waste drums and allowing gas to fill the void volume throughout the rooms and drifts. This gas will also migrate through the fractured rock to MB139 and fill the fracture volume under previous excavations. The gas pressure will rise to lithostatic (about 14 MPa), slowing the final room closure and brine inflow and maintaining open fractures in MB139. Gas generation was assumed to continue for about 2,000 yr. As gas generation slows; and pressures drop below lithostatic, brine will begin to resaturate the facility and MB139.

Case IA assumed that the 2,000-yr gas generation phase passes without untoward effects, the gas finding its way out, either through MB139 and the shaft seals or into fractures in the surrounding salt and that the facility promptly resaturates (SEIS Subsection 5.4.2.3). Case IA starts after the rooms are fully resaturated with brine, now under full lithostatic pressure and saturated with dissolved radionuclides and lead.

Figure 5.4 shows the repository system for Case IA. The preferred path for radionuclide and lead release is from the waste rooms into MB139 and through the seal in MB139 under the room seal to the base of the shafts. The transport then continues through the lower and upper shaft seals to the Culebra aquifer in the Rustler Formation. The



REF: LAPPIN et al., 1989.

FIGURE 5.4
SCHEMATIC OF THE REPOSITORY FOR CASE I, UNDISTURBED PERFORMANCE

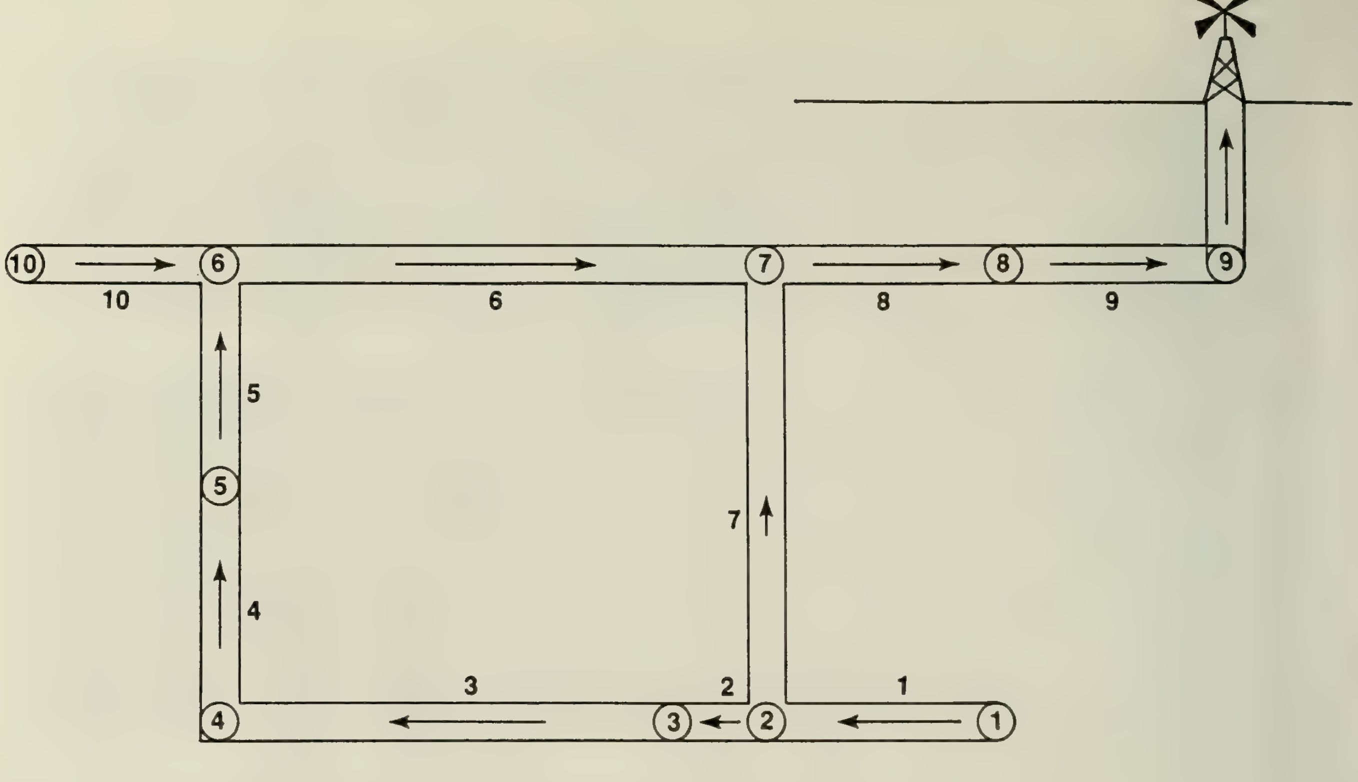
lower seal has been well consolidated by salt creep and closure about the shaft, while the upper seal will not be as well consolidated. Radionuclide and lead transport will then follow a path within the Culebra aquifer to the stock well location. Although the pathway just described is a preferred path in that each leg of the pathway has a higher permeability than the host rock, a flow path from the facility through the host rock directly toward the Culebra aquifer also must be considered because of the large cross-sectional area of the facility. This direct route is an alternative to the path through MB139 and the shaft seals.

Computer Model and Inputs. The Network Flow and TRANsport code (NEFTRAN) was developed for the Nuclear Regulatory Commission to simulate groundwater flow and radionuclide transport in an efficient manner (Longsine et al., 1987). NEFTRAN assumes that significant flow and radionuclide and lead transport take place along discrete one-dimensional legs or paths. These legs are assembled into a network representing the flow field. NEFTRAN requires pressure boundary conditions to solve the flow equations, and these conditions must be specified as part of the input (SEIS Appendix I.1.1). These boundary conditions as well as the flow network can be defined from detailed flow fields predicted by flow models such as SWIFT-II (the Sandia Waste Isolation, Flow, and Transport code) (Reeves et al., 1986a; 1986b; see also SEIS Subsection 5.4.2.6).

NEFTRAN has the ability to handle a generalized network, which the user sets up by specifying a number of legs through which flow will be calculated and the junctions at the end of each leg. The user also determines the junctions where boundary conditions are specified. The underlying assumption is conservation of mass and flow at each junction. NEFTRAN first solves the pressures at the junctions and then calculates the volume and flow rate in each leg using Darcy's Law. From these, the average fluid velocity on its tortuous path through each leg is calculated. In NEFTRAN, each radionuclide species and lead can have a different retardation factor in each leg of the migration path, and the average species velocity for each leg is treated separately. NEFTRAN uses a mean velocity for each radionuclide species and lead. It simulates the flow by keeping track of how a group of representative particles moves through each leg of the network. By this means it is able to allow for convective-dispersive transport, transport which accounts both for flow with the water and for dispersion along the path of flow. NEFTRAN can treat radionuclide chains of arbitrary length and retardation; however, it does introduce some numerical dispersion, but this can be controlled (Campbell et al., 1981).

Generalized Network for the Undisturbed Repository. A generalized flow network for Cases IA and IB is shown in Figure 5.5. Arrows indicate flow direction along each leg. Uncircled numbers are the legs. Circled numbers are nodes between legs. Legs 1 and 10 are included to establish continuous flow in the network for MB139 and the Culebra aquifer of the Rustler Formation, respectively.

The path consisting of Legs 1, 2, and 3 represents flow through MB139. Leg 2 represents the grouted seal in the marker bed that underlies the panel seal. Leg 3 represents the direct path through MB139 from that seal to the bottom of the shafts. It is assumed that this path underlies only the excavated spaces, not the pillars between



NOT TO SCALE

REF: LAPPIN et al., 1989.

NOTE: NODE 2 IS THE BOUNDARY BETWEEN THE WASTE PANEL AND MARKER BED 139. NODE 3 IS THE END OF THE MARKER BED 139 SEAL. NODE 4 IS THE BOTTOM OF THE SHAFT; NODE 5 IS THE TOP OF RECONSOLIDATED SALT IN THE SHAFT; AND NODE 6 IS THE TOP OF THE SHAFT IN THE CULEBRA DOLOMITE. NODES 10, 6, 7, 8, AND 9 SEPARATE PORTIONS OF CULEBRA DOLOMITE WITH SLIGHTLY DIFFERENT HYDROLOGIC PROPERTIES. NODE 9 IS THE HYPOTHETICAL STOCK WELL. NODES 1 AND 10 ARE INPUT NODES IN THE REPOSITORY AND CULEBRA DOLOMITE.

FIGURE 5.5

NUMERICAL FLOW NETWORK INPUT FOR SIMULATION OF CASES IA AND IB them. Leg 4 represents the consolidated lower shaft seals from the repository depth up the shaft about 200 m. This leg represents the waste shaft that has the largest diameter of the four shafts. Leg 5 simulates the poorly consolidated upper shaft seal system. Legs 6, 8, and 9 simulate the path through the Culebra aquifer to the stock well location. The hydraulic conductivities used in Legs 6 through 9 are the same as those used by LaVenue et al. (1988), and in the analysis of SEIS Subsection 5.4.2.6 below. This path was used for Cases IA and IB. Leg 7 represents a flow path directly from the panel to the Culebra aquifer through the Salado. The cross-sectional area of Leg 7 is the total floor area of the rooms and tunnels that contain waste. A second NEFTRAN run was made to calculate transport along this path and thence to the stock well along Legs 8 and 9.

The input transport parameters used for these calculations are listed in Tables 5.51 and 5.52. The transport parameter degradations in Case IB are the same as those used in SEIS Subsection 5.4.2.6 below for Cases IIB, IIC, and IID. They consist of an increased permeability in the lower shaft seal, and a decreased porosity and other changes in the Culebra aquifer.

Time Calculations. Transport calculations for radionuclides and lead were performed for the path described from Node 2 to Node 9 via Nodes 3, 4, 5, 6, 7, and 8. The arrival times for lead and the least retarded radionuclide were so long that separate calculations were made for arrival times at intermediate nodes (Table 5.53). These arrival times for the least retarded radionuclides and lead to the Culebra aquifer were based on the first arrival of reasonably detectable activities or concentration. The threshold activity used for radionuclides was 10^{-18} curies/day and the threshold concentration used for lead was 8×10^{-9} g/day.

In Case IA, the least retarded radionuclides (the uranium nuclides) were estimated to travel less than 10 m beyond the seal in MB139 in 10,000 yr. In Case IB, those radionuclides travel less than 20 m above the lower shaft seal.

Calculations were also made for transport through the host rock to the Culebra aquifer (Leg 7). For this route, there was no difference between Cases IA and IB. The arrival time for the least retarded radionuclides at the Culebra aquifer was estimated to be 400,000 yr; and at 10,000 yr, no radionuclide has travelled farther than about 10 m in the host rock. This is a shorter travel time than the 2,800,000 years calculated in Case IA. This counter-intuitive result comes from the use of Darcy's law. According to that law, travel times are proportional to the porosity and inversely proportional to the permeability. Thus, the much lower porosity in the salt than in the seals and the nearly equal permeability combine to predict an earlier arrival time along leg 7.

Based on these calculations for representative conditions and degraded conditions, there are no releases of radionuclides or lead to the Culebra aquifer in 10,000 yr, and therefore none to the hypothetical stock well. Radioactivity and lead are not available for transport through the biosphere to humans in either Case IA or IB.

TABLE 5.51 Numerical parameters input to NEFTRAN for cases IA and IB

	Permeability (m^2)		Porosity		Length of Path (m)	Cross-sectional area of path (m^2)
	IA	IB	IA	IB		
MB139 Seal (Leg 2)	4×10^{-19}	4×10^{-17}	0.03	0.03	30	0.76
MB139 (Leg 3)	3×10^{-7a}	3×10^{-7}	1.00^a	1.00	366	0.76
Lower Shaft (Leg 4)	10^{-20}	10^{-18}	0.05	0.05	200	29.2
Upper Shaft (Leg 5)	10^{-12}	10^{-12}	0.20	0.20	200	29.2
Culebra (Leg 6)	5×10^{-15}	5×10^{-15}	0.16	0.07	430	800
Culebra (Leg 8)	5×10^{-14}	5×10^{-14}	0.16	0.07	1030	800
Culebra (Leg 9)	5×10^{-13}	5×10^{-13}	0.16	0.07	3450	800
Salado host rock (Leg 7)	3×10^{-21}	3×10^{-21}	0.001	0.001	400	8030

TABLE 5.52 Numerical retardation factors input to NEFTRAN for use in cases IA and IB

Path	Retardation Factor	
MB139 Seal	1.0	for all radionuclides and lead
MB139	4.7	Pu, Th
	1.93	Am
	1.04	U, Np, Ra, Pb
Lower Shaft	5.16	Pu, Am, Th
	1.42	Np
	1.04	U, Ra, Pb
Upper Shaft	1.74	Pu, Am, Th
	1.07	Np
	1.007	U, Ra, Pb
Salado Host Rock	231	Pu, Am, Th
	240	Np
	3.3	U, Ra, Pb
Culebra	1500	Pu, Th
	3000	Am
	16	U, Np, Pb, Ra
Culebra (Case IB)	3800	Pu, Th
	7600	Am
	39	U, Np, Pb, Ra

Source: Lappin et al. 1989, Table D-7.

TABLE 5.53 Arrival times at intermediate points between the waste disposal rooms and the stock well

	To bottom of shaft	To top of lower shaft seal	To the Culebra aquifer
Case IA			
(radionuclides)	500,000 yr	900,000 yr	2,800,000 yr
(lead)	nc	nc	3,800,000 yr
Case IB	nc	8,000 yr	25,000 yr
Direct Route (Leg 7)	na	na	400,000 yr

Note: nc = not calculated
na = not applicable

Source: Lappin et al., 1989, Section 6.2

5.4.2.6 Analysis of Scenarios: Cases IIA, IIB, IIC and IID. The possible exposure pathways for these Cases start with the release of material to the surface at the top of the intruding well. Three kinds of releases are possible: first, the drill head penetrates a repository panel removing cuttings; second, particles are eroded from the consolidated waste by the circulating drilling mud and entrained Castile brine; and third, some Salado brine enters the borehole to be carried to the surface.

The eroded drill hole diameter was assumed to be the same in all four cases. No allowance was made for the fact that the compacted waste in Cases IIB and IIC will be more resistant to erosion than that in Cases IIA and IID.

Drilling practices used in the Delaware Basin are described in Lappin et al. (1989). A hole, assumed to be 13-1/8 inches (33.4 cm) in diameter was drilled to the Rustler, then cased. When the hole reached the brine reservoir in the Castile Formation, the pressurized brine showed a pressure pulse in the drilling mud. The drilling crew would add weight to the drilling mud (probably by adding barite) to stop flow into the hole. In the process little brine would be released as such at the surface, because its progress upward would be slower than that of the pressure pulse. Nevertheless, during the 80 hours needed to drill from the Castile brine reservoir down to oil presumed to be in the underlying Bell Canyon Formation, the circulating mud was assumed to bring up to the surface 1000 barrels of brine from the Castile reservoir, some waste eroded from the repository, and some Salado Formation brine.

A cylindrical volume of waste was brought to the surface out of the repository. Its diameter was estimated as the 33.4-cm diameter of the drill bit plus a calculated 10-cm additional erosion around for a total diameter of 53.4 cm. Its height was 107 cm, this being the expected thickness of the repository after closure. The net volume of 240 liters was equivalent to almost three compacted drums.

Eighty hours of Salado Formation brine inflow at 1.3 m^3/yr is 12 liters and, for a radionuclide solubility of 10^{-4} molar, (Cases IIB and IIC), this Salado brine will carry with it the equivalent of about 1/100 drum of radionuclides. For Cases IIA and IID, the quantity of radionuclides will be much less.

This material would be discharged into a settling pond (also called a mud pit) at the surface adjacent to the well. While members of the drill crew could be exposed externally to this material, the principal exposure would be to a geologist who examines the drill cuttings.

The same approach as the one used in the FEIS (Subsection 9.7.1.5) was used to estimate the external dose to the geologist. Assuming the geologist examines a cuttings sample for one hour from a distance of 1 m, the exposure was calculated as if the sample is a point source that was not self-shielded. The estimated doses are given in Table 5.54, assuming drilling is directly through a compressed drum of CH TRU waste and a cuttings sample size of 526 cm^3.

TABLE 5.54 Maximum dose received by a drilling-crew member due to exposure to contaminated drilling cuttings

Nuclide	Activity/sample (mCi)	Energy/gamma (MeV)	n (-q/dis)	Exposure (mrem/hr)
Pu-238	35	0.099	8.0×10^{-5}	1.4×10^{-4}
Pu-239	4	(no gamma)		
Pu-240	1	0.65	2.0×10^{-7}	6.5×10^{-8}
U-233	0.06	0.029	1.7×10^{-4}	1.5×10^{-7}
U-235	3.2×10^{-6}	0.14-0.20	0.05-0.54	3.0×10^{-7}
Am-241	7.1	0.06	0.36	0.077
Np-237	7.3×10^{-5}	(no gamma)		
Total				0.077

Source: Lappin et al. (1989) Table 7.5

The radiation exposure rate from natural background in the United States is approximately 100 mrem/yr, or approximately 0.01 mrem/hr. The background is somewhat higher at the WIPP site, where the altitude is about 3,000 ft. The exposure rate of 0.077 mrem/hr to the geologist is eight times the background, but the expsoure only lasts one hr.

After drilling operations cease, radioactive material remaining in the settling pond becomes available for transport through airborne or surface-water pathways. Doses to a ranch family hypothesized to live 500 m downwind from the settling pond were assessed in the FEIS (Subsections 9.7.1.6 and K.3.1). The calculation was conservative, because most lands in this arid region are federally owned and not available for habitation. However, the dose estimates are repeated for completeness.

The pathways that result in radiation doses to the hypothetical ranch family begin with the transport of respirable particles from the settling pond by wind erosion. Surface water was not considered avialble transport mode in the FEIS and it is not considered in this analysis. The pathways are the same as those considered in the FEIS. They include:

- Inhalation of contaminated air
- Ingestion of foods (meat, milk, and above and below-surface food crops) produced on the ranch.

The estimated committed doses to individual members of this family are given in Table 5.55. These are the radiation doses that the person would receive during the next 50 yr as the result of a one yr exposure. Therefore, this person receives 0.0015 mrem/yr on the average, or 0.015 percent of his/her annual background exposure. Over this 50 yr period, the body burden would build up, so that in the 50th year the person would receive an exposure of 0.077 mrem.

Similarly the calculated concentration of lead in the ambient air at the hypothetical ranch is 5.16×10^{-12} mg/m^3, and the ground surface deposition is 1.63×10^{-9} g/m^2. Assuming a 70-kg man breathing 20 m^3/day, and that 35 percent of this material is absorbed into the body, his daily intake of lead is 5.16×10^{-13} mg/kg-day.

TABLE 5.55 Committed dose equivalent after 1-year exposure (mrem/50 yr)

Nuclide	Beef	Milk	Above-surface Crops	Below-surface Crops	Inhalation[a]
Am-241	3.04×10^{-12}	9.97×10^{-11}	8.81×10^{-11}	1.03×10^{-10}	2.62×10^{-1}
Np-237	8.23×10^{-17}	4.86×10^{-16}	4.20×10^{-13}	nc[b]	2.58×10^{-6}
Pu-238	1.69×10^{-14}	2.69×10^{-16}	3.30×10^{-11}	1.35×10^{-10}	4.37×10^{-1}
Pu-239	1.98×10^{-15}	3.15×10^{-17}	3.87×10^{-12}	1.58×10^{-11}	5.40×10^{-2}
Pu-240	4.94×10^{-16}	7.89×10^{-18}	9.68×10^{-13}	3.95×10^{-12}	$1.35 \mathrm{X} 10^{-2}$
U-233	5.87×10^{-15}	6.22×10^{-14}	1.59×10^{-13}	7.29×10^{-14}	$2.62 \mathrm{X} 10^{-4}$
U-235	2.93×10^{-19}	3.11×10^{-18}	7.95×10^{-18}	3.65×10^{-18}	$1.19 \mathrm{X} 10^{-8}$
Total ingested dose:			4.91×10^{-10}		
Total inhaled dose:					7.66×10^{-1}

Source: Lappin et al. (1989), Table 7.8

[a] Assumes a breathing rate of 2.7×10^{-4} m^3/s

[b] nc = not calculated

The estimate of the daily intake of lead by humans calculated in this manner can be compared to the level for chronic intake (AIC) described in the Superfund Public Health Evaluation Manual (EPA, 1986). This level is 4.3×10^{-4} mg/kg-day. The calculated AIC-based hazard index for lead is therefore $5.16 \times 10^{-13} / 4.3 \times 10^{-4} = 1.2 \times 10^{-9}$. This value is well below one, indicating that the intake of stable lead is well below the level of chronic intake. The dose calculated for inhalation is the most direct, and therefore the highest pathway for lead intake. Because of the small quantity of lead deposited on the ground surface, and the even smaller amounts potentially taken up by animals and plants, it can be safely assumed that all other potential pathways in this scenario (i.e., ingestion of vegetables, milk, and meat) will be orders of magnitude below health-based levels.

and plants, it can be safely assumed that all other potential pathways in this scenario (i.e., ingestion of vegetables, milk, and meat) will be orders of magnitude below health-based levels.

Post-Plugging Analysis: Models and Codes. In the analysis of the four variants of Case II, the SWIFT-II model was used to: 1) simulate the release of fluid from a hypothetical brine reservoir connected via a borehole through the repository to the Culebra aquifer, 2) simulate the flow field within the Culebra aquifer, and 3) simulate transport of contaminants in the fractured Culebra dolomite. SWIFT-II is a fully transient, three-dimensional code that solves the coupled equations for transport in geologic media. The processes considered in this application are:

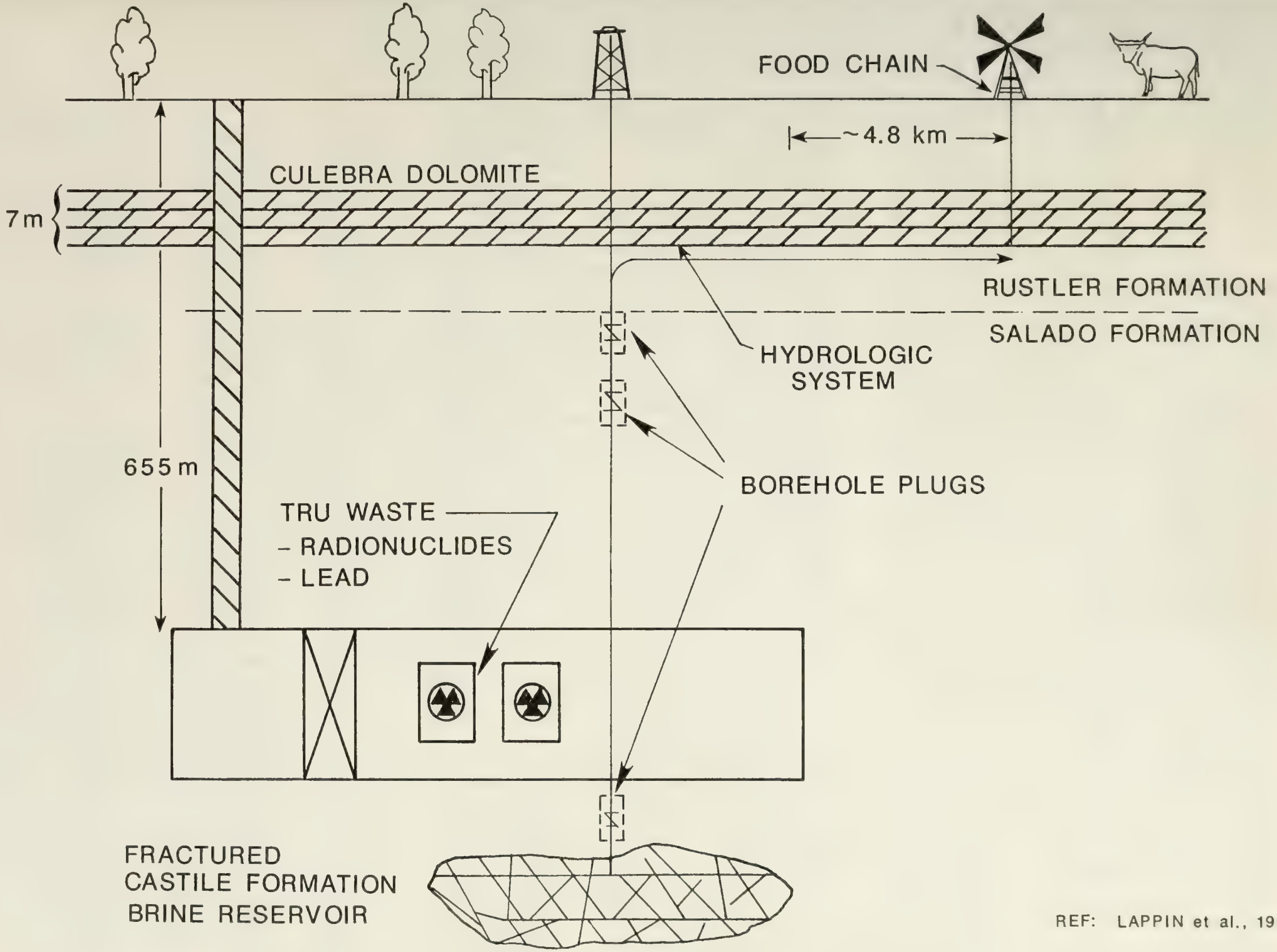
- Dual-porosity fluid flow, accounting for matrix porosity and fracture flow
- Movement of a dominant solute (salts)
- Trace-species movement (radionuclide chains and stable lead).

SWIFT-II has been in continuous development and upgrading since 1975 and is supported by comprehensive documentation and an extensive testing history (Reeves et al., 1986a,b). It is one of the most extensively verified codes in current use for the analysis of radioactive-waste transport in groundwater.

Figure 5.6 indicates the main features of a brine-reservoir breach. It shows a borehole that passes through the repository and connects a brine reservoir to the Culebra aquifer. LaVenue et al. (1988) describe in detail the most recent model of flow in the Culebra aquifer; they used the SWIFT-II code to calibrate the steady-state model of regional flow within the aquifer. The analysis summarized here uses that model, combining the pressurized brine reservoir and the borehole analytically as a source term.

The brine reservoir is idealized as a porous disk whose properties vary with distance from its center. The flow would be radially inward to the bottom of a borehole, then upward. The inward flow causes a pressure drawdown in the reservoir that, together with the flow itself, must be matched to the pressure and flow in the borehole.

As the brine passes the waste repository, it would pick up a burden of dissolved radionuclides and stable lead. For Case IIA, the hydraulic conductivity of the waste panel ($1x10^{-6}$ m/s) was assumed to be high enough for the Castile brine to pick up its full burden of waste radionuclides and stable lead before continuing up the borehole. This circulation was assumed to be limited to a single waste panel that contains eight rooms and two long access tunnels filled with waste and backfill. During this circulation, the brine would dissolve waste to a solubility limit of $1x10^{-6}$ molar for the radionuclide constituents and 116 mg/l for stable lead, if available. Brine inflow from the Salado Formation would provide a second, smaller source of fluid that would move through the repository and bring dissolved waste radionuclides into the borehole flow. The long-term brine inflow rate from the Salado has been conservatively estimated at 1.3 m^3 per yr for a single waste panel.



REF: LAPPIN et al., 1989.

FIGURE 5.6
SCHEMATIC OF THE REPOSITORY AND UNDERLYING CASTILE FORMATION BRINE RESERVOIR FOR CASE II, PERFORMANCE WHEN DISTURBED BY HUMAN INTRUSION

For Case IIB, compaction of the waste, and backfilling the remaining void volume would reduce the hydraulic conductivity of the waste panel to 1 x 10^{-11} m/s. It can be safely assumed that the Castile brine cannot circulate through the waste and dissolve radionuclides and lead. The only remaining source of contaminated fluid entering the borehole would be brine inflow from the Salado Formation (Table 5.50).

Case IIB assumed the same brine inflow rate (1.3 m^3 per yr per panel) that was used in Case IIA. This rate is conservative since no credit was taken for the reduced hydraulic conductivity causing a reduction in the brine inflow rate.

Cast IIC is similar to Case IIB, except that Case IIC assumed that the waste is not precompacted so that the Castile brine flows through the repository. Case IID incorporated degraded groundwater transport projection, expected values for radionuclide solubility (same as Case IIA values), and pretreatment of the waste and backfill that eliminated Castile brine flow through the repository and reduced Salado brine inflow rates.

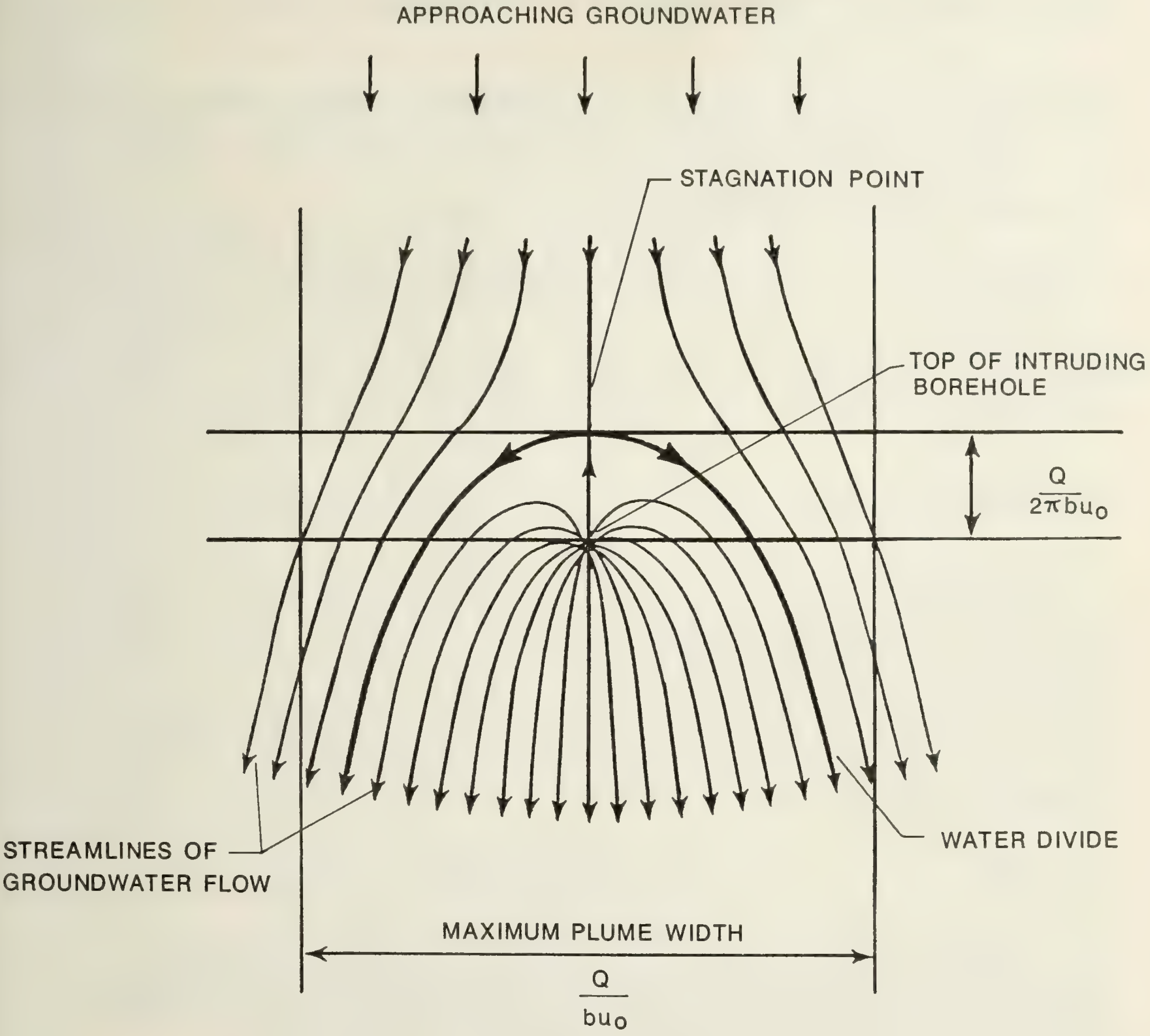
Two more assumptions in these repository source terms are to be noted. First, the characterization of waste transport solely as dissolved species assumed that colloid formation and transport and particulate transport were minor. Second, Case II assumed that waste-generated gas would vent from the room when drilling intercepted the repository. Given that this scenario involved just one drill hole in an entire waste panel, it is possible that the system behaved in a more heterogeneous manner, with the gas produced in more distant parts of the panel helping to drive fluid up the borehole. This process, however, could not be evaluated in a quantitative fashion at the present time (SEIS Subsection 5.4.2.4).

Flow Calculations. The rate of fluid release from the brine reservoir into the Culebra aquifer was calculated, taking into account degradation of the plugs installed in the intruding borehole when it was abandoned and depressurization of the brine reservoir. Then the analysis turns to the calculation of centerline radionuclide and stable lead concentrations in the down-stream waste plume to the hypothetical stock well 3 miles away.

In calculating the transport of radionuclides and lead in the Culebra aquifer, the numerical model assumed that the amount of brine entering from the intruding borehole was small enough that the Culebra aquifer flow continued almost undisturbed.

The brine entering flows to the south with the Culebra aquifer flow in a plume that slowly widens down-flow. Initially, the streamlines of brine flow spread out from the point of injection but at a distance they become nearly parallel to the direction of natural groundwater flow (Figure 5.7).

Asymptotically, the streamlines of the injected fluids form a fluid of contaminated water of width Q/bu_o, where Q is the rate of fluid release, b is the aquifer thickness, and u_o is the natural groundwater flux. Also, the flux within the plume approaches that of the natural groundwater. The plume width and stagnation distance also provide a measure



NOTE: Q = RATE OF FLUID RELEASE, m^3/s

b = AQUIFER THICKNESS, m

u_o = GROUNDWATER FLOW , m/s

REF: LAPPIN et al., 1989.

FIGURE 5.7

DIAGRAM OF GROUNDWATER FLOW NEAR THE POINT WHERE WATER FROM THE INTRUDING BOREHOLE ENTERS CULEBRA AQUIFER FLOW

TABLE 5.56 Dimensions of the waste plume in the Culebra aquifer

	Case IIA	Cases IIB, IIC, IID
Distance from release to stagnation point		
- 75 yr	7.8 m	69.6 m
- 10,000 yr	5.6 m	4.7 m
Plume width at 75 yr		
- near release point	49.2 m	437 m
- at stock well	21.2 m	188 m
Plume width at 10,000 yr		
- near release point	35.2 m	29.3 m
- at stock well	15.1 m	12.5 m
Centerline concentration reduction factor at stock well		
- at 75 yr	37	4.2
Rate of fluid injection		
- at 75 yr	3.5×10^{-7} m^3/s	3.2×10^{-6} m^3/s
- at 10,000 yr	2.5×10^{-7} m^3/s	2.1×10^{-7} m^3/s

of the extent of disturbance to the natural flow. The maximum rate of fluid release, Q_{max}, and the natural groundwater velocity u_o at the point of injection yield the stagnation-point distances and the plume widths shown in Table 5.56.

In the SEIS calculations, the radionuclides and stable lead were followed along the stream line with the maximum concentration. The width of the stream tube around this central stream line was chosen to match the velocities of flow in the surrounding aquifer.

Lateral dispersion. The "stream tube" approach neglected the effect of lateral dispersion, resulting in an overestimation of solute concentration along the plume centerline. Such effects, however, were approximated, and a "reduction factor" has been developed. This factor is inherently greater than one; it is the factor by which the calculated concentrations are divided to correct for the effects of lateral dispersion and provide an approximation of the true centerline concentrations. The dispersion factor at the stock well at 10,000 yr was calculated using a transverse diffusivity a tenth the value adopted for the longitudinal diffusivity. The values used in the SEIS calculations are those listed in Table 5.56 for 75 yr: 37 for Case IIA and 4.2 for Cases IIB, IIC, and IID.

Stream tube modeling. As indicated, the model uses a one-dimensional stream tube extending from the source to the stock well. In principle, such a stream tube requires a constant rate of fluid injection, whereas the actual rate decreases with time.

In Cases IIA and IIC, radionuclide concentrations are constant, because brine would be saturated, having circulated through the repository panel. In Cases IIB and IID, however, concentrations would increase with time, because a constant amount of saturated brine from the Salado flow into a decreasing amount of fluid from the Castile brine reservoir. Another effect of a time-varying rate is that the plume width would be altered. Table 5.56 indicates that the stagnation-point distance decreases by a factor of 15 over the 10,000-yr time scale being considered. However, because these changes are slow, they can be treated as quasi-steady-state phenomena.

Input Parameters to the Model. Some of the parameters assumed for these calculations are given in Tables 5.57 and 5.58.

For the most part, these parameters are the same for all four cases. The same brine reservoir assumptions are made throughout (Table 5.57). In Table 5.58, the permeability of the borehole was assumed to be ten times larger for Cases IIB, IIC, and IID than for Case IIA; this accounts for the ten times greater initial rates of fluid injection shown in Table 5.56. Similarly, the solubility of waste radionuclides in brine was assumed to be 100 times greater in Cases IIB and IIC than in Cases IIA and IID. Brine inflow from the Salado was ten times larger in Cases IIA, IIB, and IIC than in IID. Culebra flow projections were degraded to make the groundwater flow faster and easier in Cases IIB, IIC, and IID than in IIA.

These differences are summarized in Table 5.50.

Radionuclide Concentrations at the Stock Well. Figure 5.8 contrasts the flow rates for Cases IIA and IIB. (Those for IIC and IID will be like those for IIB). Here time starts when the plugs in the borehole begin to fail at 75 years after emplacement then, for ease in computation they are assumed to fail in steps at 75, 100, 125, and finally at 150 yr. The initial flow in Case IIB at 75 years would be ten times greater than that in Case IIA, then the rate decreases sharply as the Castile Formation brine reservoir depletes. The lower initial flow in Case IIA (due to a lower borehole permeability, as shown in Table 5.58) depletes the reservoir much more slowly, and the curve is nearly flat for the 10,000 yr calculated. At 10,000 years, there would be a larger flow in Case IIA than in Case IIB.

For all radionuclides considered, Case IIA yields negligible concentrations at the stock well after 10,000 yr (Table 5.59).

Figures 5.9 and 5.10 show how the concentrations vary with distance from the intruding borehole at 10,000 yr for stable lead and three radionuclides in the Pu-238 chain in Case IIA. (The concentrations shown in Figures 5.9 through 5.14 are before corrections

TABLE 5.57 Base-case and range of values of parameters describing the brine reservoir

Parameter	Symbol	Base-case	Range	Units
Initial pressure	P_i	12.7	7.0 to 17.4	MPa
Effective thickness	b	7.0	7.0 to 24.0	m
Transmissivity of inner zone	T_i	7×10^{-4}	7×10^{-6} to 7×10^{-2}	m^2/s
Distance to intermediate zone contact	r_2	300	100 to 900	m
Transmissivity of intermediate zone	T_o	7×10^{-6}	7×10^{-8} to 7×10^{-4}	m^2/s
Distance to outer zone contact	r_3	2000	30 to 8600	m
Transmissivity of outer zone	T_m	1×10^{-11}	Constant	m^2/s
Fluid density	ρ_f	1240	Constant	kg/m^3
Porosity	ϕ	0.005	0.001-0.01	
Compressibility of medium	α	1×10^{-9}	1×10^{-10} to 1×10^{-8}	1/Pa

TABLE 5.58 Specifications for intrusion borehole for Case II simulations

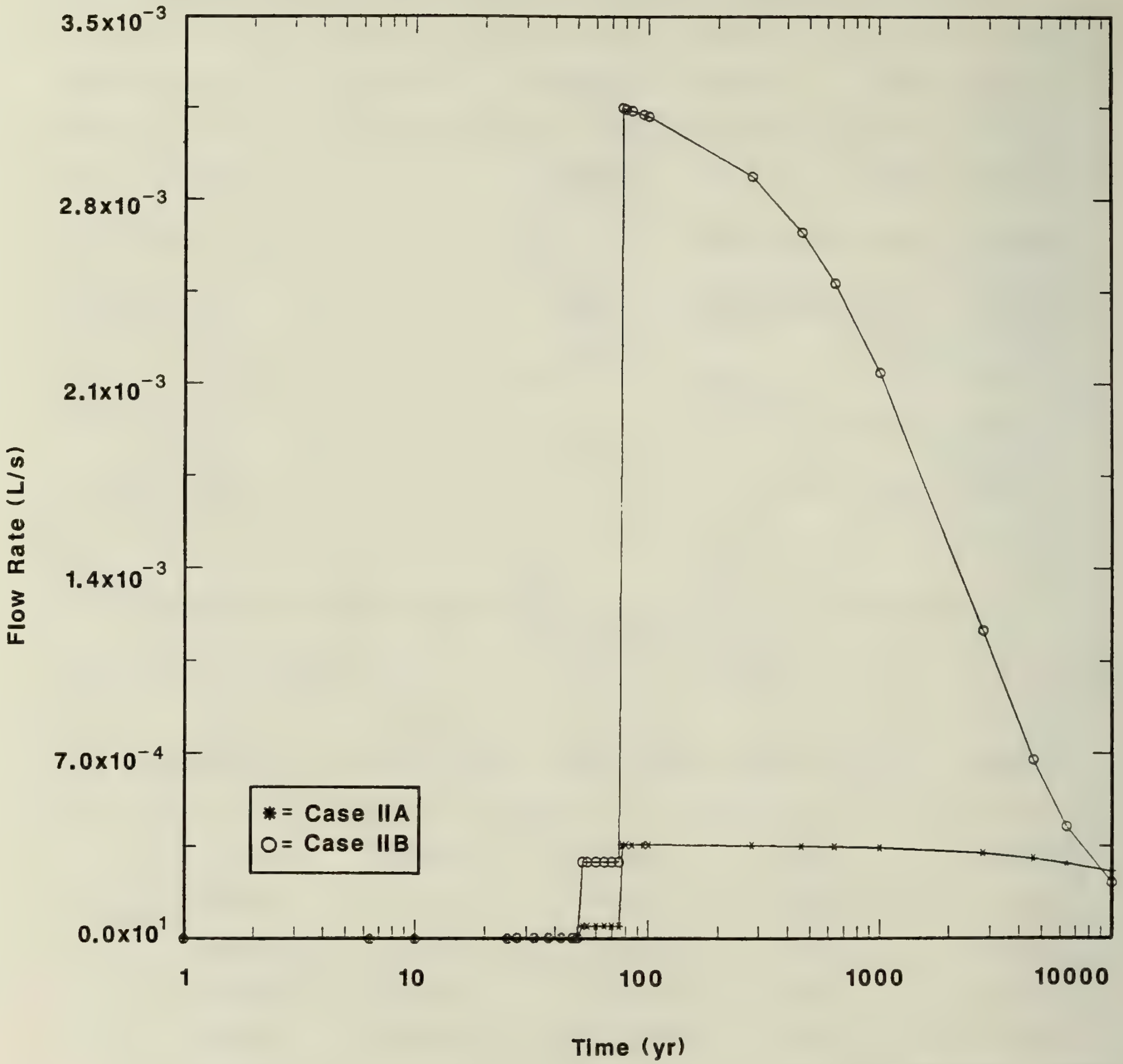
Parameter	Value	Units
Borehole diameter	0.334	m
Effective borehole permeability		
- Open borehole between plugs	infinite	
- plug in Castile	10^{-15}	m^2
- plugs in Salado	10^{-18}	m^2
- for times greater than 150 yr		
- Case IIA	10^{-12}	m^2
- Case IIB, IIC, and IID	10^{-11}	m^2

TABLE 5.59 Radionuclide concentrations in the Culebra aquifer at the stock well at 10,000 yr[a]

Nuclide	Case IIA (kg/kg brine)	Case IIB (kg/kg brine)	Case IIC (kg/kg brine)	Case IID (kg/kg brine)
Np-237	nd[b]	8.37×10^{-9}	2.98×10^{-8}	2.57×10^{-10}
Pb-210	7.61×10^{-19}	1.20×10^{-13}	4.15×10^{-1}	1.46×10^{-15}
Pu-239	nd	8.36×10^{-10}	4.14×10^{-1}	6.58×10^{-13}
Pu-240	nd	1.07×10^{-10}	2.32×10^{-1}	3.83×10^{-13}
Ra-226	5.46×10^{-17}	8.63×10^{-12}	2.98×10^{-1}	1.05×10^{-13}
Th-229	nd	3.65×10^{-11}	1.58×10^{-1}	1.52×10^{-13}
Th-230	8.21×10^{-23}	9.01×10^{-12}	1.57×10^{-1}	1.20×10^{-13}
U-233	nd	2.92×10^{-8}	8.59×10^{-8}	2.55×10^{-10}
U-234	1.68×10^{-18}	7.94×10^{-9}	2.86×10^{-8}	2.56×10^{-10}
U-236	nd	7.71×10^{-9}	8.84×10^{-9}	7.40×10^{-11}

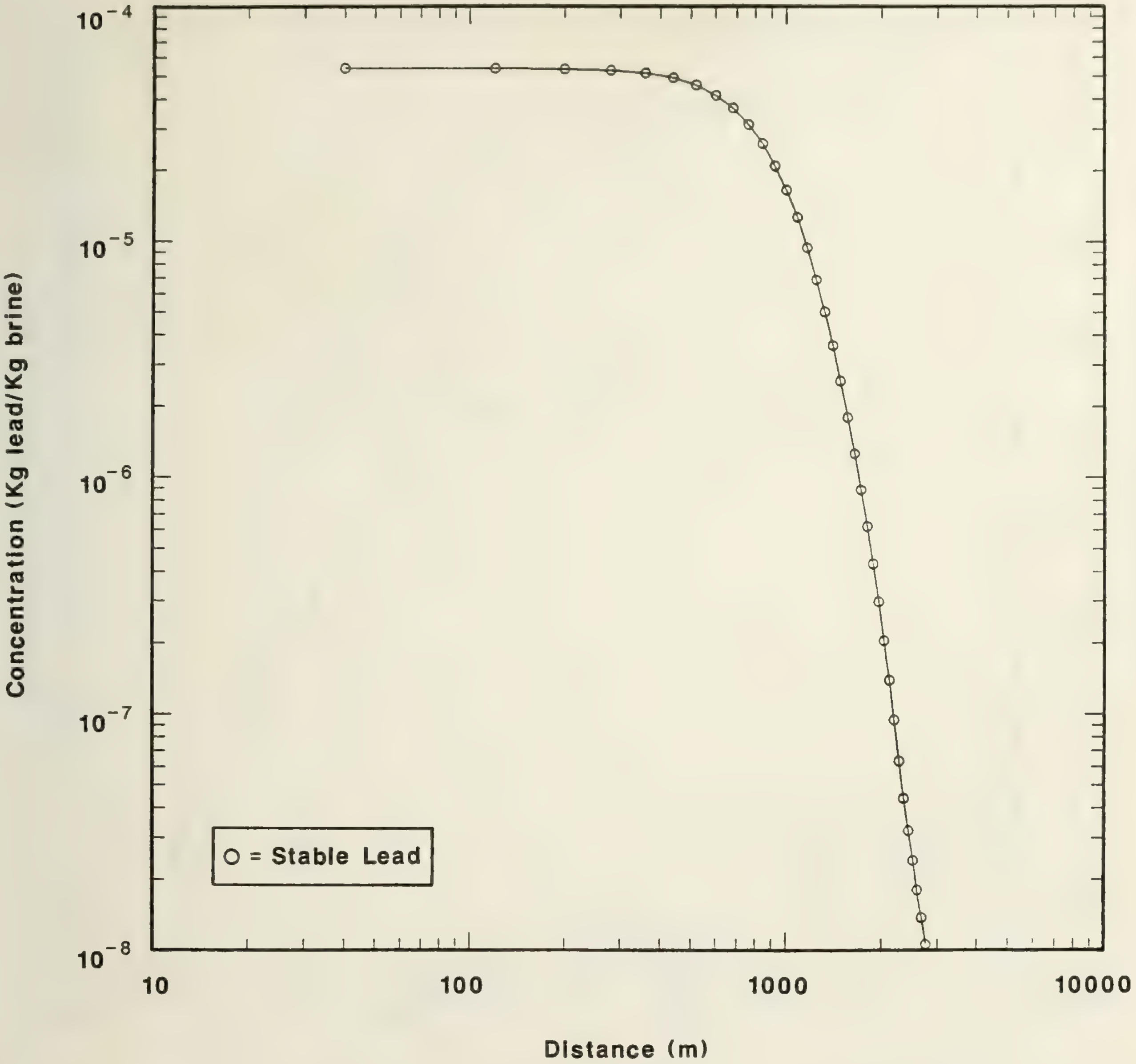
[a] 1500 years for Case IIC

[b] nd = not detected



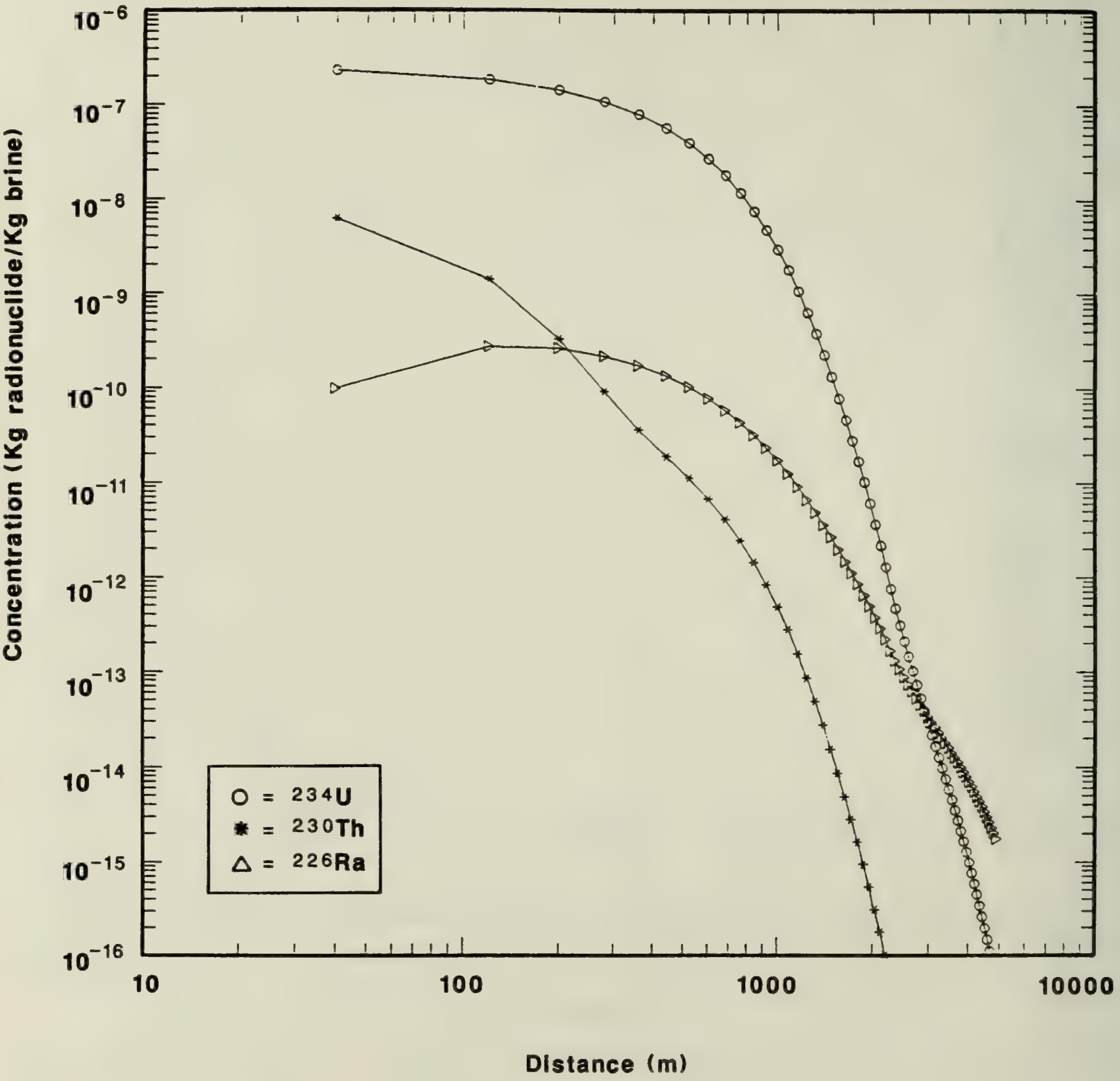
REF: LAPPIN et al., 1989.

FIGURE 5.8
FLOW RATES IN THE CULEBRA AQUIFER
FROM THE BREACH BOREHOLE FOR CASES IIA AND IIB



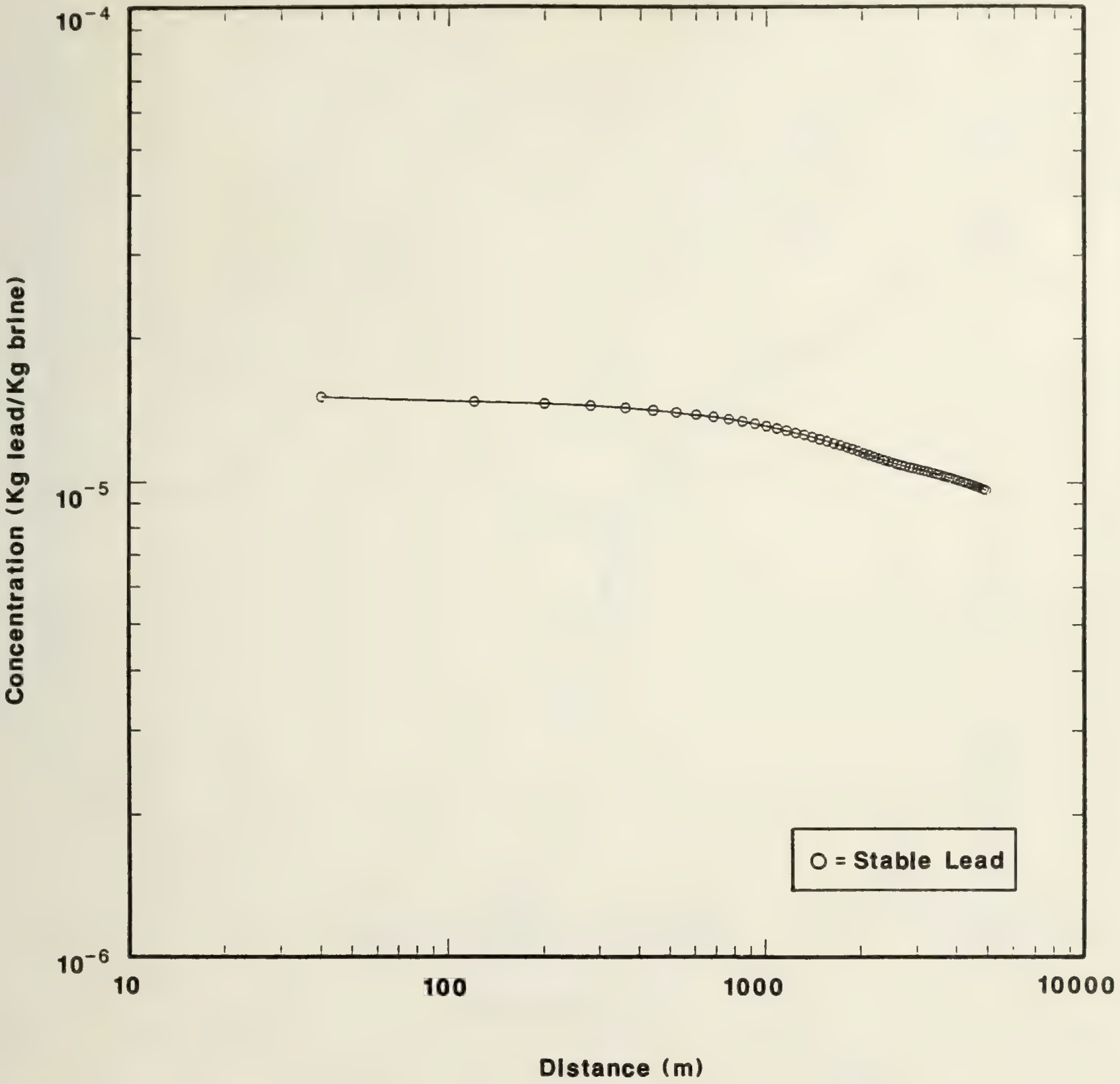
REF: LAPPIN et al., 1989.

FIGURE 5.9
STABLE LEAD CONCENTRATION PROFILE
AT 10,000 YEARS FOR CASE IIA



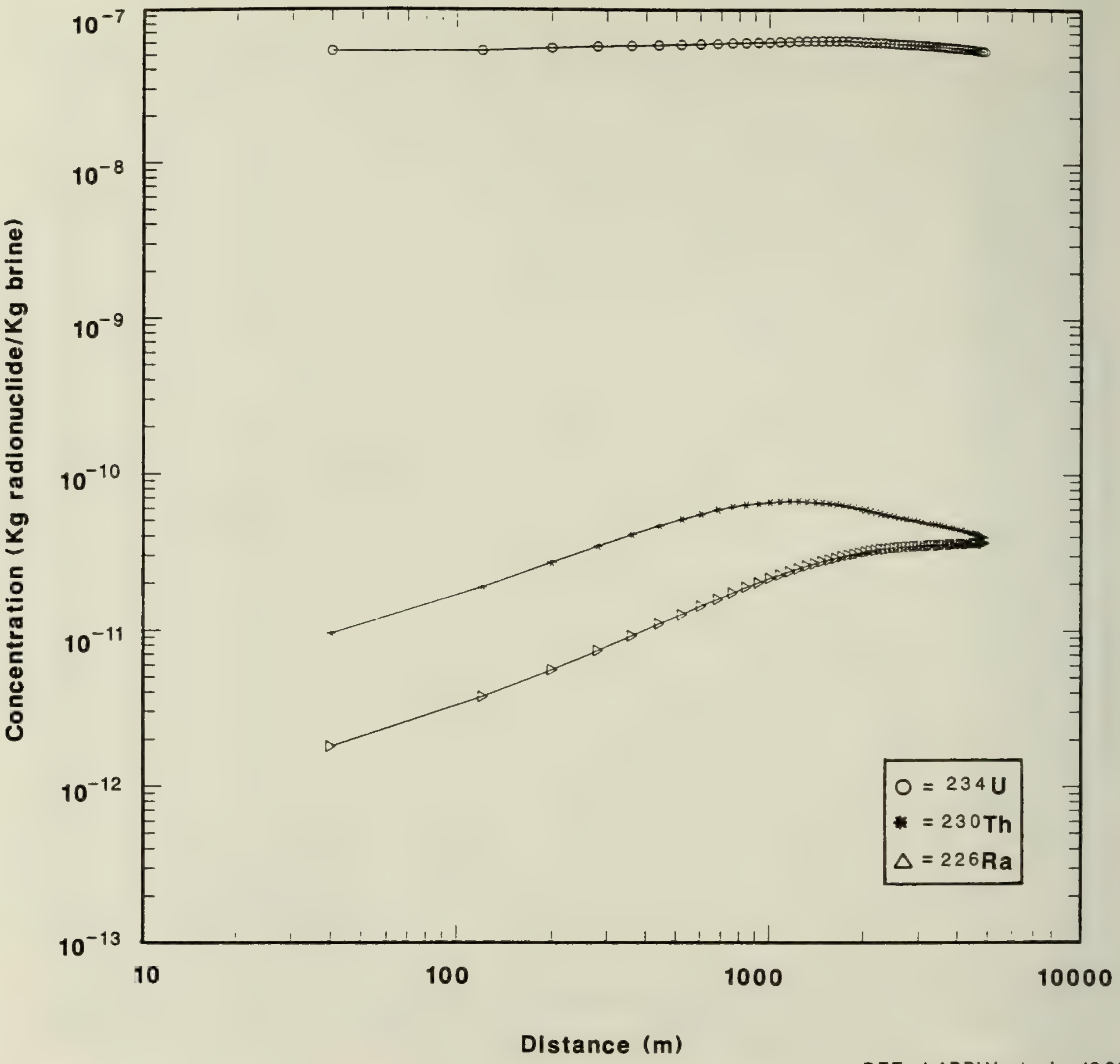
REF: LAPPIN et al., 1989.

FIGURE 5.10
RADIONUCLIDE CONCENTRATION PROFILES
AT 10,000 YEARS FOR CASE IIA



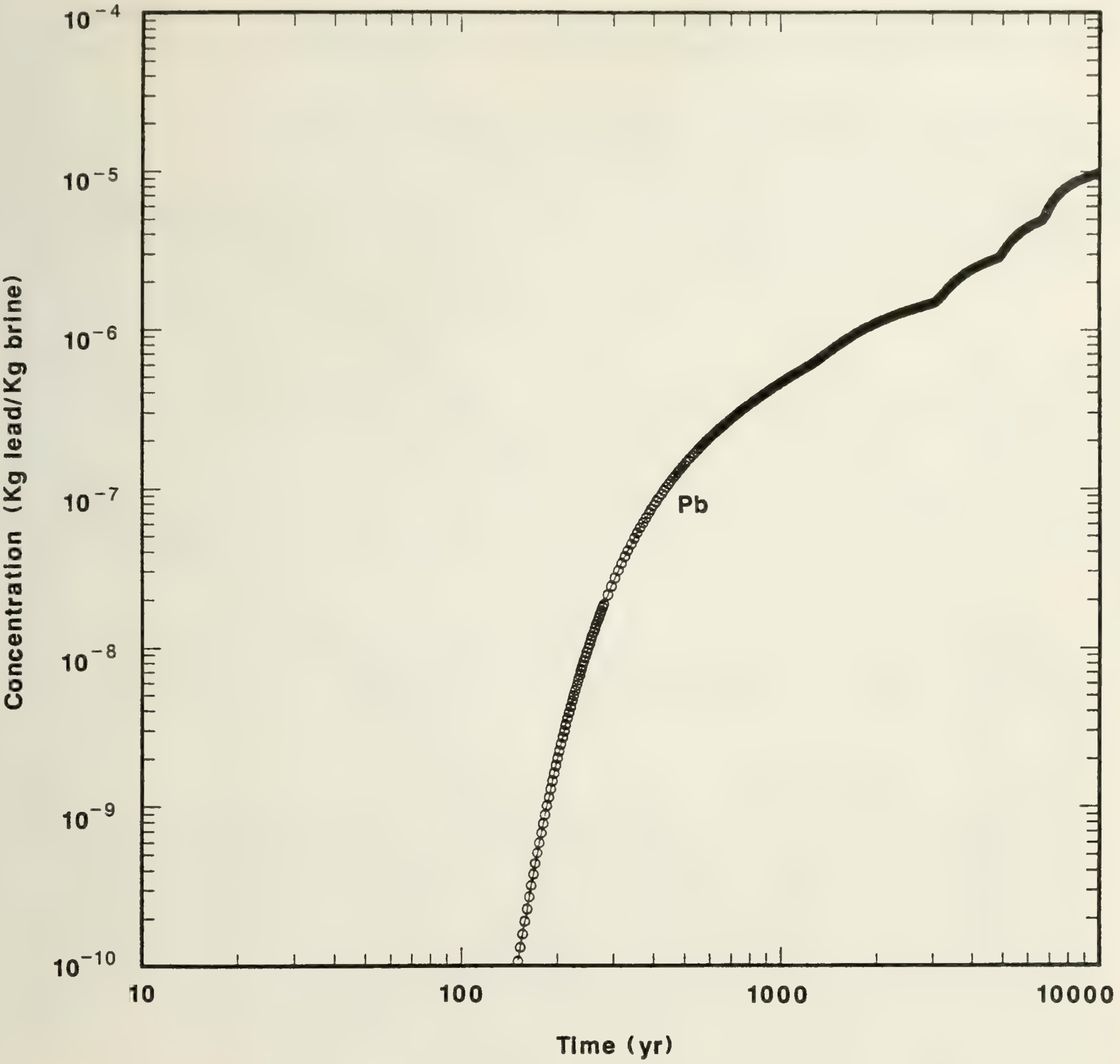
REF: LAPPIN et al., 1989.

FIGURE 5.11
STABLE LEAD CONCENTRATION PROFILE
AT 10,000 YEARS FOR CASE IIB



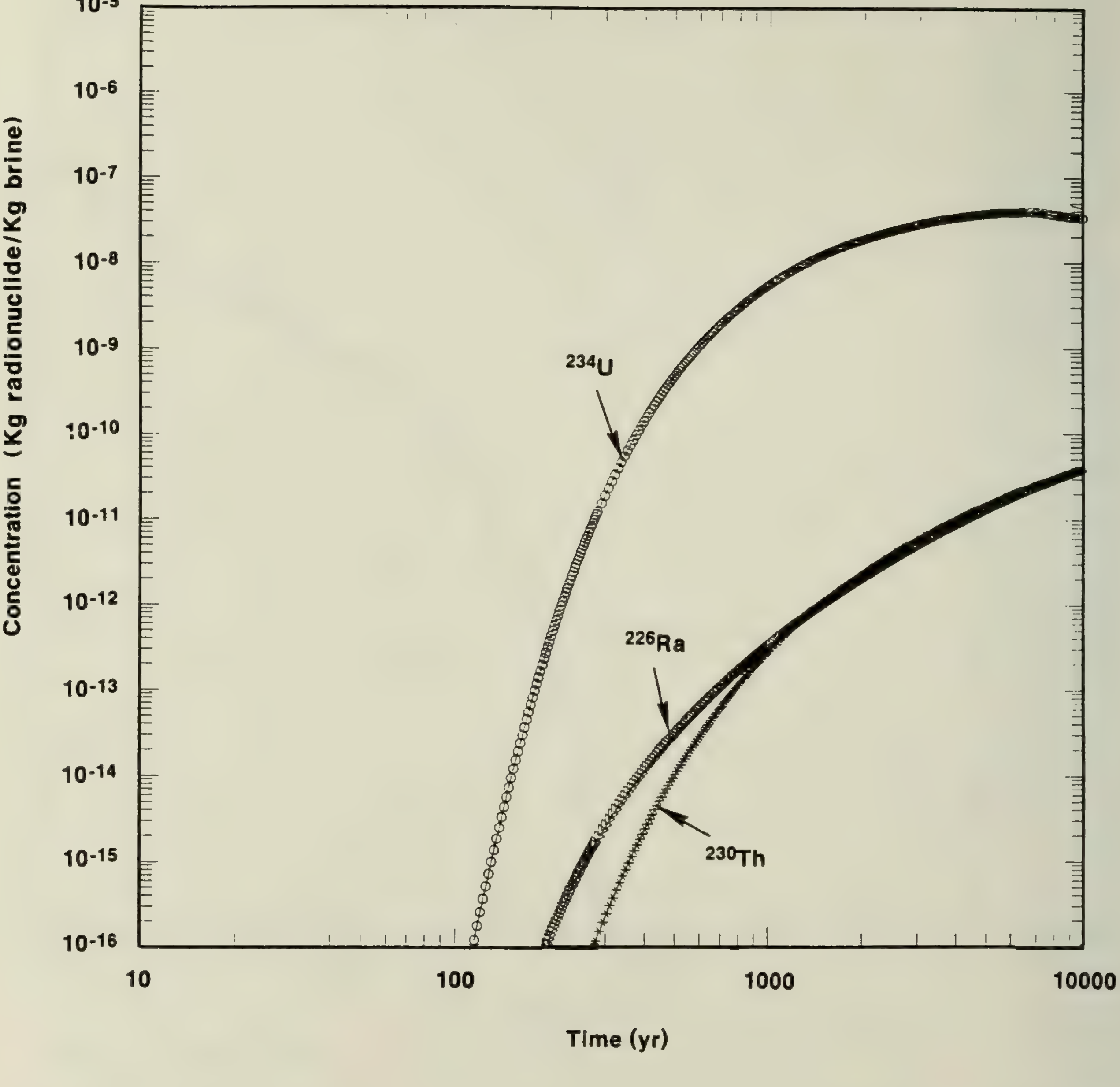
REF: LAPPIN et al., 1989.

FIGURE 5.12
RADIONUCLIDE CONCENTRATION PROFILES
AT 10,000 YEARS FOR CASE IIB



REF: LAPPIN et al., 1989.

FIGURE 5.13
BREAKTHROUGH AND BOUNDARY CONCENTRATIONS
OF STABLE LEAD AS A FUNCTION OF TIME FOR CASE IIB



REF: LAPPIN et al., 1989.

FIGURE 5.14
BREAKTHROUGH AND BOUNDARY CONCENTRATIONS
OF RADIONUCLIDES AS A FUNCTION OF TIME FOR CASE IIB

were made for lateral dispersion by dividing the numbers plotted by 37 in Case IIA and by 4.2 for Case IIB.) Only Ra-226 and U-234 arrive at the stock well, 3 mi distant, in (uncorrected) concentrations over 10^{-16} kg(nuclide)/kg(brine) by 10,000 yr.

In contrast to Case IIA, in Case IIB a number of radionuclide species would arrive at the stock well in appreciable concentrations by 10,000 yr. Figures 5.11 and 5.12 show how concentrations vary with distance for stable lead and the Pu-238 chain in that case. Figures 5.13 and 5.14 show how the concentrations of those elements would change with time at the stock well. Stable lead arrives at the stock well in about 150 yr (Figure 5.13), and by 10,000 yr its front is so far beyond the well that its concentrations are very nearly the same at all distances plotted (Figure 5.11).

Table 5.60 quantifies the changes in Culebra transport parameters that cause this qualitative difference between the cases. For Cases IIB, IIC and IID, porosity is reduced from 16 to 7 percent. The distribution coefficients k_d are also reduced, so that there is less retardation: for Pb and Ra this reduction is from 0.1 to 0.05 ml/g. The fracture spacing is increased from 2 to 7 m, so that, the fracture porosity remaining the same, the fracture widths increase from 0.3 to 1.0 cm. These and other changes all increase the rate of fluid transport in the fractures above that of Case IIA.

Increasing the fracture spacing also decreases the area of matrix exposed to the fluid by a factor of 3.5, thereby reducing the opportunity for diffusion into the matrix to occur. The importance of the rock matrix is evident when one notes that, without diffusion into the rock matrix, the contaminants would require only about 150 yr to reach the stock well.

Radiation Exposures from Stock Well Water. All four variants of Case II assumed that water pumped from the stock well was given to cattle grazing in the area. The human exposure calculated here would be to a person who eats beef from those cattle. The calculations assumed that 8 cattle graze in the square mi (2.6 km^2) around the well. Each animal would require 13 gal/day (50 l/day) of water to drink. Thus, allowing for rainfall at the rate of 20 cm/yr and evaporation at the rate of 200 cm/yr and a stock pond whose area is 139 ft^2 (0.0013 hectare), means that this well must be pumped at the rate of 120 gal/day (460 l/day).

Finally, assuming that the maximally exposed individual eats beef from these cattle at the rate of 86 g/day (NCRP, 1984) and using the usual transfer coefficients for relating the amount of food eaten to exposure of the various body organs, the calculation yields the individual committed doses shown in Table 5.61.

The committed doses shown in Table 5.61 are the maximum doses that the beef eater could receive during the first 10,000 years after the intruding borehole is abandoned and plugged. The earliest time that this intrusion could occur is at 100 years after the facility is decommissioned (40 CFR 191), because active institutional controls are assumed to prevent the intrusion at any earlier time. (Such an early intrusion is unlikely because the site will be well marked and well recorded.) At any later time the amount of radioactivity in the repository will have decayed to a lower value, but this calculation only allows for decay after the intrusion.

TABLE 5.60 Parameter base-case and range values selected for the Culebra dolomite

Parameter	Symbol	Base Case	Range	Units
Free-water diffusivity	D'	5×10^{-6}	5×10^{-7} - 9×10^{-5}	cm^2/s
- Radionuclides - Case IIA	D'	1×10^{-6}	n.a.	cm^2/s
- Cases IIB, IIC, IID	D'	5×10^{-7}	n.a.	cm^2/s
- Stable Pb - Case IIA	D'	4×10^{-6}	n.a.	cm^2/s
- Cases IIB, IIC, IID	D'	1×10^{-6}	n.a.	cm^2/s
Matrix tortuosity		0.15	0.03 - 0.5	
- Case IIA		0.15	n.a.	
- Cases IIB, IIC, IID		0.03	n.a.	
Fracture Spacing	2L'	2.0	0.25 - 7.0	m
- Case IIA	2L'	2.0	n.a.	m
- Cases IIB, IIC, IID	2L'	7.0	n.a.	m
Porosity	ϕ	0.16	0.07 - 0.30	
- Case IIA	ϕ	0.16	n.a.	
- Cases IIB, IIC, IIC	ϕ	0.07	n.a.	
Fracture porosity	ϕ	1.5×10^{-3}	1.5×10^{-4} - 1.5×10^{-2}	
Matrix distribution coefficient				
- Case IIA: Plutonium	k_d	50	-	ml/g
Americium	k_d	200	-	ml/g
Uranium	k_d	1	-	ml/g
Neptunium	k_d	1	-	ml/g
Thorium	k_d	50	-	ml/g
Radium	k_d	0.1	-	ml/g
Lead	k_d	0.1	-	ml/g
- Cases IIB, IIC, IID:				
Plutonium	k_d	25	-	ml/g
Americium	k_d	100	-	ml/g
Uranium	k_d	1	-	ml/g
Neptunium	k_d	1	-	ml/g
Thorium	k_d	25	-	ml/g
Radium	k_d	0.05	-	ml/g
Lead	k_d	0.05	-	ml/g

Note: The Culebra groundwater flow model presented in LaVenue et al. (1988) was used for calculating fluxes and determining flow paths. The transient fracture flux along the flow path from the release point in the Culebra aquifer to the off-site stock well is calculated through hydraulic coupling of the brine reservoir, borehole region, and Culebra aquifer.

In Cases IIA, IIB, and IID the maximum calculated committed dose occurs at the end of the 10,000 year period. The curve of dose vs. time is still rising at that time; the actual maximum will occur later. This should not be surprising because a key purpose of geological disposal is to delay the appearance of containments in the accessible environment for very long times. Calculations could be extended past 10,000 years, but they become more and more meaningless.

In Case IIC, however, a maximum calculated dose appears at about 1500 years after borehole abondonment (Figure 5.15); this maximum is the one shown in Table 5.61. The dose contributions of the two radionuclides (U-233 and U-234) that principally contribute to this maximum are also shown. However, the dose curve is rising again at the end of the 10,000 year period (see the Pb-210 curve; Pb-210 is a short-lived daughter in secular equilibrium with Ra-226). This indicates that if calculations were extended to a later time, another maximum would appear. This later maximum is the result of more retarded radionuclides reaching the stock well.

For Case IIC, the most severe case, the 129-mrem dose shown in Table 5.61 is the committed dose that a person eating contaminated beef watered at the stock well would receive during the next 50 yr as the result of a one-year exposure. Thus this person receives an average annual exposure of 2.6 mrem from that one year's commitment. This person will continue to eat beef, and in his or her 50th year of eating beef at this rate, he or she will receive a 129-mrem radiation dose, about 30 percent over the 100-mrem average annual background in the United States.

Lead Exposures from Stock Well Water. This calculation assumed that beef cattle drink water from the stock pond that contains the maximum concentration of lead (2.31 mg/l at 10,000 yr) at the rate of 49 liters (13 gal) per day. An average steer weighs 400 kg (Merck, 1979). A factor of 0.15 is used to account for the fact that not all of the lead ingested by cattle is retained in the beef (a portion of it will be excreted). Thus, the cattle will take up and retain lead at the rate of

$$2.31(\text{mg/l}) \times 49(\text{l/day}) \times 0.15/400(\text{kg}) = 0.043 \text{ mg/kg-day}.$$

The steer will not be harmed; it has been estimated that a mature steer will tolerate 6 mg/kg-day lead for two to three yr (Botts, 1977).

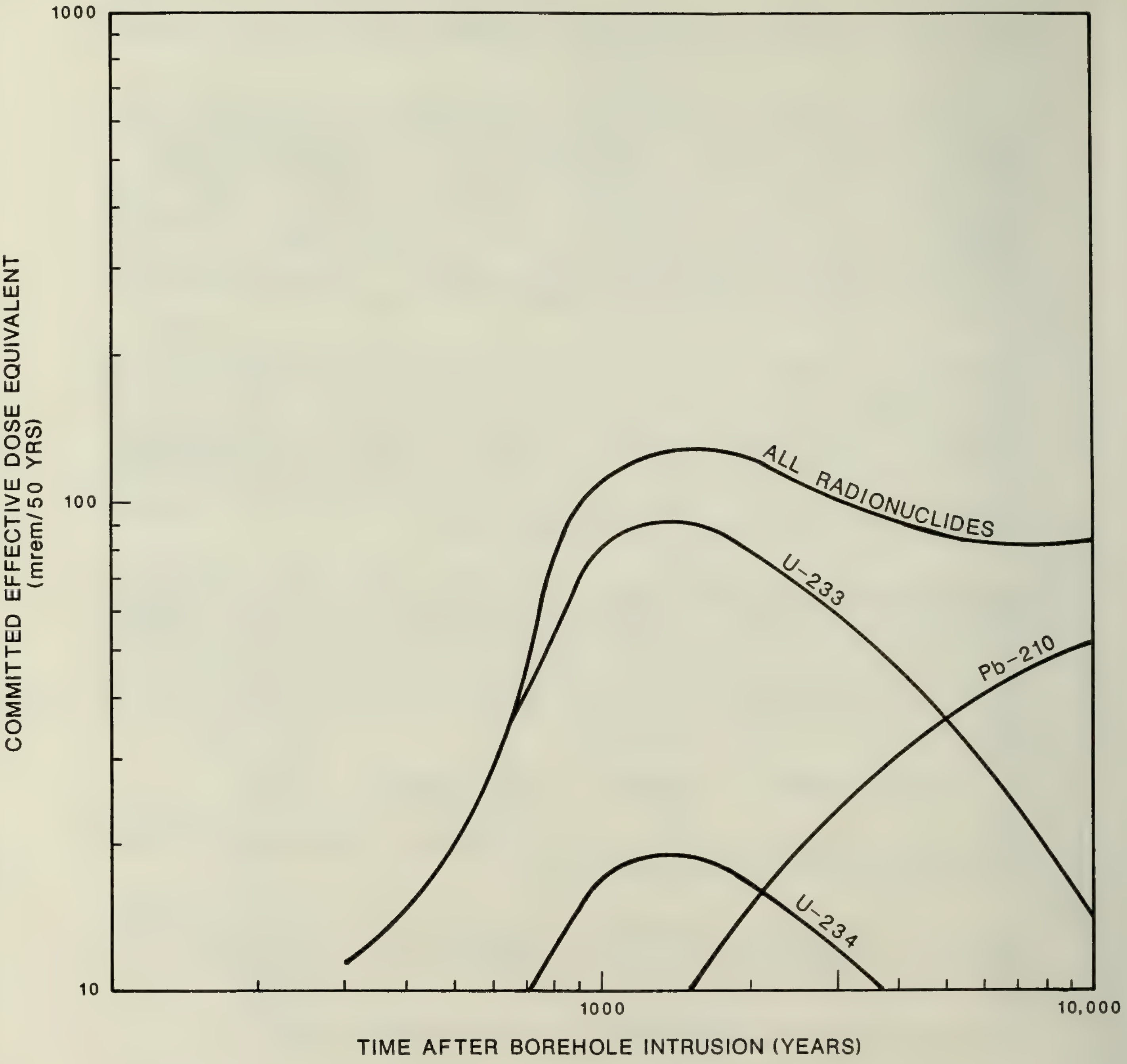
Then, assuming that the concentration of lead in the stock water remains constant throughout the lifetime of the steer, and that the ratio of the concentration of lead in the beef to that in the water is 3×10^{-4} $(\text{kg/day})^{-1}$,

$$2.31(\text{mg/l}) \times 3\times10^{-4}(\text{day/kg}) \times 49(\text{l/day}) = 0.034 \text{ mg(lead)/kg(beef)}$$

will be available for human consumption.

As above, an adult male (age 19 to 50) is taken to consume 0.086 kg of beef daily. An adult male body weight averages 70 kg. The daily human intake of lead, using the figure just calculated of 0.034 mg/kg of lead in the beef consumed and a gut partition factor of 0.15, is

$$0.034(\text{mg/kg}) \times 0.086(\text{kg/day}) \times 0.15/70(\text{kg}) = 6.27\times10^{-6} \text{ mg/kg-day}.$$



NOTE: CONTRIBUTION OF THREE PRINCIPAL RADIONUCLIDES AND ALL RADIONUCLIDES

FIGURE 5.15

RADIATION DOSES TO INDIVIDUALS WHO EAT BEEF FROM CATTLE WATERED AT THE STOCK WELL FOR CASE IIC

Table 5.61 Maximum 50-year committed doses incurred by an individual eating beef for one year that was watered at a stock well tapping a contaminated Culebra aquifer, for four scenarios (mrem/50 yr)

Nuclide	Case IIA	Case IIB	Case IIC	Case IID
Np-237	nd	2.54	9.06	7.81×10^{-2}
Pb-210	1.78×10^{-4}	$2.82 \times 10^{+1}$	9.72	3.43×10^{-1}
Pu-239	nd	2.25×10^{-1}	1.11×10^{-5}	1.77×10^{-4}
Pu-240	nd	1.06×10^{-1}	2.28×10^{-5}	3.77×10^{-4}
Ra-226	3.02×10^{-5}	4.77	1.64	5.79×10^{-2}
Th-229	nd	$3.28 \times 10^{+1}$	1.42×10^{-1}	1.36×10^{-3}
Th-230	1.06×10^{-14}	1.16×10^{-1}	4.60×10^{-4}	1.55×10^{-5}
U-233	nd	$3.06 \times 10^{+1}$	$9.02 \times 10^{+1}$	2.67×10^{-1}
U-234	1.10×10^{-9}	5.18	$1.87 \times 10^{+1}$	1.67×10^{-1}
U-236	nd	5.01×10^{-2}	5.75×10^{-2}	4.81×10^{-4}
Total	2.09×10^{-4}	$7.20 \times 10^{+1}$	$1.29 \times 10^{+2}$	9.15×10^{-1}

Note: nd = not detected

The estimate of the daily intake of lead by humans calculated in this manner can be compared to the acceptable daily level for chronic intake (AIC) according to procedures described in the Superfund Public Health Evaluation Manual (EPA, 1986) Appendix G. This level is 4.3×10^{-4} mg/kg-day (EPA, 1986). The calculated AIC-based hazard index for lead is therefore:

$$6.27 \times 10^{-6} / 4.3 \times 10^{-4} = 0.015.$$

This value is considerably less than one, indicating that the estimated intake of lead is well below the reference level. In other words, the ingestion of this concentration of lead every day throughout the life of the consumer will not result in adverse health effects.

5.4.2.7 Summary.

Human Exposure. The results of the Case IIB and IIC analyses indicate the dose levels that can be predicted using degraded groundwater transport properties (see Appendix I, Subsection I.2). But even these yield results that are of the same order of magnitude as natural background radiation in the United States. More likely assumptions in Cases IIA and IID predict much lower doses.

The doses listed are "50-year committed effective dose equivalents." They are the total radiation doses that a person eating for one year beef that had been watering at the contaminated stock well for one year would receive during the next 50 years. Assuming that this person continues to eat beef from this source, his or her body burden of these transuranic radionuclides would continue to accumulate, and in the 50th year of such accumulation, he or she would receive a radiation dose numerically equal to the figures listed in Table 5.61.

By international agreement (ICRP 1977, 1979), a committed dose is charged (in an accounting sense) against a person's radiation exposure during the year in which it is incurred. For radionuclides with long residence times within the body, notably the transuranics of concern in this SEIS, this means that the dose is charged before it is actually received. This agreement allows for the fact that in many instances, the radionuclide ingestion giving the committed dose is repeated year after year.

Cases IA and IB treat the undisturbed repository. No radionuclides reach the Culebra aquifers or the surface within 10,000 years; therefore there is no human exposure in that time.

Case IIA treats the expected behavior of the disturbed repository. A drill hole passes through it to an underlying brine reservoir, bringing some radionuclides and lead directly to the surface and also allowing them to enter the Culebra aquifers. The doses to a ranch family near the well head are at most a 0.77 mrem 50-year committed effective dose for each year of exposure.

Cases IIB, IIC, and IID treat the performance of the disturbed repository under various degraded conditions. The doses to persons at or near the well head are similar to those in Case IIA. In Case II, lead exposures at the well head and as a result of eating beef from the stock well are well below the EPA health protection reference level.

Case IIB predicts a maximum committed dose of about 72 mrem/50yr. Case IIB predicts doses almost a million times greater than Case IIA because: the radionuclides in the waste are assumed to be 100 times as soluble; the borehole is assumed to be 10 times as permeable, and therefore the flow up the shaft is 10 times as great; and the Culebra parameters are degraded so as to permit a much more rapid flow toward the stock well. In Case IIB the earliest radionuclides (U-233, U-234, and Np-237) show up at the stock well at only a few hundred years after the borehole plugs fail; even the plutonium isotopes arrive at about 1000 years. By contrast, in Case IIA only Ra-226 and U-234 arrive within 10,000 years.

Case IIC predicts the highest total dose of the four cases. The only difference from Case IIB is that in Case IIC the waste is not compacted, so that the borehole brine is able to pick up its full burden of waste radionuclides. (This saturation is assumed to be immediate.) The flow is so great that the panel "soon" (in a few thousand years) starts to be depleted of its radionuclides, and the dissolved radioactivity enters the Culebra groundwater as a "pulse." Down stream, because the individual radionuclides have different K_ds, they are differently retarded and their peaks arrive at the stock well at different times. Ra-226, U-233, and U-234 peak at about 1300 yr, the other radionuclides much later. As a result, the Case IIC peak is 129 mrem/50 yr at about 1500 yr after the intruding borehole is abandoned and plugged, whereas the Case IIB peak is some time after 10,000 yr, with the committed dose at 10,000 yr being 72 mrem/50 yr.

In Case IID the borehole and aquifer parameters are degraded to the same extent as in Case IIB, but the net dose listed in Table 5.61 is 100 times lower. This arises from two facts: the radionuclide solubilities are assumed lower by a factor of 100, back to the expected value used in Case IIA, and the brine inflow from the Salado Formation into and through the waste is reduced from 1.3 m^3/year from one panel to 0.1 m^3/yr from one room. As in Case IIB, the only source of radionuclides to be carried to the Culebra by the borehole brine is that which is dissolved in brine inflow from the Salado Formation. The resulting much lower rate of discharge of radioactivity into the Culebra at the top of the borehole yields a much lower concentration of radionuclides at the stock well.

In summary, the undisturbed repository is not expected to release any radioactive materials to the environment in 10,000 years, even if its solubility and groundwater flow parameters are considerably poorer than expected (Cases IA and IB). In all four Case II intrusion scenarios, radioactive material is brought to the surface immediately, but exposures to the drill crew and to a near-by downwind ranch family are well below the usual guidelines. For example, the ICRP recommends (ICRP, 1977) and the DOE has adopted a 100 mrem/yr general dose limit for a member of the general public from human practices other than in the medical field. The expected behavior of the disturbed repository (Case IIA) is well within these guidelines. If, however, the groundwater flow parameters are considerably poorer than expected (Cases IIB and IIC), the doses predicted are at or above those guidelines. Precompaction of the waste appear to reduce the predicted doses by 44 percent (Case IIB vs. Case IIC). If, more realistically, the waste radionuclides are assumed to have the same solubility as in Case IIA and if the inflow of brine from the Salado Formation is assumed to be decreased by the waste consolidation (Case IID), the predicted committed doses are again well within the guidelines.

Integrated releases. The calculations performed to calculate radionuclide concentrations at an assumed stock well due to human intrusion cannot be used, as such, to establish total integrated release at a controlled boundary over a 10,000 year period. To do these calculations properly, even in a deterministic fashion, would require fully two-dimensional calculations of hydrologic transport in the Culebra aquifer. One can, however, bound the releases over time out to 10,000 years using simplified analyses.

These may provide some insight, in the absence of defensible, probabilistic-performance-assessment evaluations, about the prospects that the WIPP will comply with the long term release criteria specified in 40 CFR 191.

To deduce integrated releases from the existing calculations, one must assume that the width of the radioactive plume at the stock well does not change during the entire 10,000 years, even though it is known that the plume width does change with time. Although the proposed land withdrawal boundary is only 2 mi (3.2km) south of the center of the site, the hypothesized stock well is the only location at which the concentration histories have been calculated. Therefore, concentrations were calculated along a hypothetical boundary located at the stock well 3 mi (5km) south of the center of the site. By assuming a maximum plume width at the stock well boundary over the entire 10,000 years, an upper bound to the integrated release can be obtained. Assuming a minimum plume width for the entire 10,000 years at the stock well boundary, a smaller value for the integrated release is obtained. Both these calculations are conservative in that this simplified analysis assumes that all contaminants travel along the fastest flow path without any lateral dispersion. With these assumptions one can integrate the release at the stock well boundary for each radionuclide over the 10,000 year period and determine the normalized release using the release limits specified in Appendix A of 40 CFR 191.

The radionuclides used to calculate the WIPP release limits are restricted to those identified in the EPA standard, Table 1, Appendix A; namely transuranic alpha-emitting isotopes with half-lives greater than 20 years. The best estimate of the total inventory for WIPP of these isotopes is 5.1×10^6 curies. Consequently, the releases limits are 5.1 times the total values listed in Table 1, which were for 10^6 curies of TRU waste. The additional radioactivity that brings the total curie inventory for the WIPP up 9.68×10^6 curies are fission products or transuranics of less than 20 year half-life or non-alpha emitters.

Tables 5.62 through 5.65 give the resultant release limits by radionuclide for the effective CH-TRU waste curies (5.1×10^6 curies) in the total initial WIPP inventory (9.68×10^6 curies), the bounding and lower value release quantities for the four variations of Case II, and the ratio of the released curies for each Case II scenario to the release limits specified in the standard.

In order to calculate an integrated release for Case IIA, additional assumptions were necessary. Transport to the stock well was minimal in Case IIA with only the most mobile radionuclides, Ra-226 and Pb-210, predicted to reach the stock well within 10,000 years. Therefore, only the Pu-238 chain was directly included in the integrated release calculated Case IIA. Because no source depletion occurs in Case IIA over the 10,000-year simulation period, maximum concentrations for radionuclides in the Am-241 chain can be estimated based on the transport behavior analogous to that of the Pu-238 chain. Concentrations from the Am-241 chain were then included in the calculation. The relatively high K^ds controlling transport of Pu-240 and Pu-239 and the expected low concentrations of the U-236 daughter indicate that concentrations of these radionuclides will be insignificant relative to the concentrations of radionuclides in the Pu-238 and Am-241 chains. Assuming that the concentration of each radionuclide in these two chains is equal to it's maximum concentration at the stock well over the entire 10,000 years, a conservative estimate of integrated released can be made for Case IIA. Table 5.62 gives the resultant upper-bounding and lower value release for Case IIA.

The total release for the upper bound analysis (associated with assuming a maximum width plume) ranges from 4.86 times the total release limit in the standard for Case IIC (Table 5.64), the most severe case, down to 9.08 x 10^{-7} times the release limit for Case IIA (Table 5.62), the expected case. The lower values of total release (associated with the minimum width plume) ranges from 0.323 times the standards' limit for Case IIC down to 6.51 x 10^{-7} times the standards' limit for Case IIA. The resultant upper-bounding and lower value releases for Cases IIB and IID are intermediate between

TABLE 5.62 Integrated release calculation: Case IIA

Radionuclide	Release Limit[a]	Maximum Curies	Maximum /RL	Minimum Curies	Minimum /RL
Np-237	510.0	$4.88\text{x}10^{-9}$	$9.57\text{x}10^{-12}$	$3.49\text{x}10^{-9}$	$6.84\text{x}10^{-12}$
Pb-210	510.0	$2.40\text{x}10^{-4}$	$4.71\text{x}10^{-7}$	$1.72\text{x}10^{-4}$	$3.37\text{x}10^{-7}$
Pu-239	510.0	NA[b]	NA	NA	NA
Pu-240	510.0	NA	NA	NA	NA
Ra-226	510.0	$2.23\text{x}10^{-4}$	$4.37\text{x}10^{-7}$	$1.60\text{x}10^{-4}$	$3.14\text{x}10^{-7}$
Th-229	510.0	$7.13\text{x}10^{-11}$	$1.40\text{x}10^{-13}$	$5.10\text{x}10^{-11}$	$1.00\text{x}10^{-13}$
Th-230	51.0	$6.85\text{x}10^{-12}$	$1.34\text{x}10^{-13}$	$4.90\text{x}10^{-12}$	$9.61\text{x}10^{-14}$
U-233	510.0	$6.57\text{x}10^{-8}$	$1.29\text{x}10^{-10}$	$4.70\text{x}10^{-8}$	$9.22\text{x}10^{-11}$
U-234	510.0	$4.34\text{x}10^{-8}$	$8.51\text{x}10^{-11}$	$3.11\text{x}10^{-8}$	$6.10\text{x}10^{-11}$
U-236	510.0	NA	NA	NA	NA
		SUM MAX:	$9.08\text{x}10^{-7}$	**SUM MIN:**	$6.51\text{x}10^{-7}$

[a] Except for Th-230, the release limits are 100 times the number of waste units. One TRU Waste unit is 10^6 Ci of Alpha-emitting transuranic radionuclides with half-lives over 20 years (40CFR191).

[b] NA = release is less than that for Pu-238 and Am-241 chains

TABLE 5.63 Integrated release calculation: Case IIB

Radionuclide	Release Limit	Maximum Curies	Maximum /RL	Minimum Curies	Minimum /RL
Np-237	510.0	2.14×10^{1}	4.20×10^{-2}	1.42×10^{0}	2.78×10^{-3}
Pb-210	510.0	1.53×10^{1}	3.00×10^{-2}	1.02×10^{0}	2.00×10^{-3}
Pu-239	510.0	3.79×10^{1}	7.43×10^{-2}	2.52×10^{0}	4.94×10^{-3}
Pu-240	510.0	2.41×10^{1}	4.73×10^{-2}	1.60×10^{0}	3.14×10^{-3}
Ra-226	510.0	1.42×10^{1}	2.78×10^{-2}	9.45×10^{-1}	1.85×10^{-3}
Th-229	510.0	1.52×10^{1}	2.98×10^{-2}	1.01×10^{0}	1.98×10^{-3}
Th-230	51.0	3.27×10^{-1}	6.41×10^{-3}	2.17×10^{-2}	4.25×10^{-4}
U-233	510.0	1.00×10^{3}	1.96×10^{0}	6.65×10^{1}	1.30×10^{-1}
U-234	510.0	1.82×10^{2}	3.57×10^{-1}	1.21×10^{1}	2.37×10^{-2}
U-236	510.0	1.07×10^{0}	2.10×10^{-3}	7.10×10^{-2}	1.39×10^{-4}
		SUM MAX:	2.58×10^{0}	**SUM MIN:**	1.71×10^{-1}

TABLE 5.64 Integrated release calculation: Case IIC

Radionuclide	Release Limit	Maximum Curies	Maximum /RL	Minimum Curies	Minimum /RL
Np-237	510.0	3.77×10^{1}	7.4×10^{-2}	2.51×10^{0}	5.0×10^{-3}
Pb-210	510.0	4.26×10^{1}	8.4×10^{-2}	2.84×10^{0}	6.0×10^{-3}
Pu-239	510.0	3.34×10^{2}	6.55×10^{-1}	2.22×10^{1}	4.4×10^{-2}
Pu-240	510.0	2.09×10^{2}	4.1×10^{-1}	1.39×10^{1}	2.7×10^{-2}
Ra-226	510.0	3.96×10^{1}	7.8×10^{-2}	2.63×10^{0}	5.0×10^{-3}
Th-229	510.0	3.06×10^{1}	6.0×10^{-2}	2.04×10^{0}	4.0×10^{-3}
Th-230	51.0	8.52×10^{-1}	1.7×10^{-2}	5.67×10^{-2}	1.0×10^{-3}
U-233	510.0	1.45×10^{3}	2.84×10^{0}	9.62×10^{1}	1.89×10^{-1}
U-234	510.0	3.20×10^{2}	6.27×10^{-1}	2.13×10^{1}	4.2×10^{-2}
U-236	510.0	6.19×10^{0}	1.2×10^{-2}	4.11×10^{-1}	8.1×10^{-4}
		SUM MAX:	4.86×10^{0}	**SUM MIN:**	3.23×10^{-1}

TABLE 5.65 Integrated release calculation: Case IID

Radionuclide	Release Limit	Maximum Curies	Maximum /RL	Minimum Curies	Minimum /RL
Np-237	510.0	2.56×10^{-1}	5.02×10^{-4}	1.42×10^{-2}	2.78×10^{-5}
Pb-210	510.0	1.17×10^{-1}	2.29×10^{-4}	6.48×10^{-3}	1.27×10^{-5}
Pu-239	510.0	2.89×10^{-2}	5.67×10^{-5}	1.60×10^{-3}	3.14×10^{-6}
Pu-240	510.0	6.40×10^{-2}	1.25×10^{-4}	3.54×10^{-3}	6.94×10^{-6}
Ra-226	510.0	1.09×10^{-1}	2.14×10^{-4}	6.02×10^{-3}	1.18×10^{-5}
Th-229	510.0	3.54×10^{-2}	6.94×10^{-5}	1.96×10^{-3}	3.84×10^{-6}
Th-230	51.0	2.60×10^{-3}	5.10×10^{-5}	1.44×10^{-4}	2.82×10^{-6}
U-233	510.0	3.42×10^{0}	6.71×10^{-3}	1.89×10^{-1}	3.71×10^{-4}
U-234	510.0	2.26×10^{0}	4.43×10^{-3}	1.25×10^{-1}	2.45×10^{-4}
U-236	510.0	5.23×10^{-3}	1.03×10^{-5}	2.90×10^{-4}	5.69×10^{-7}
		SUM MAX:	1.24×10^{-2}	**SUM MIN:**	6.85×10^{-4}

those for Cases IIC and IIA. Table 5.63 gives the resultant releases for Case IIB and Table 5.65 gives the resultant releases for Case IID.

Only the upper bound deterministic calculations for Cases IIB and IIC exceed the standard; the lower values of release for these two cases are below the released limit. The calculations for Cases IIB and IIC assume a combination of degraded parameters with a low probability of occurrence (see Table 5.50), and in the upper bound analysis, conservatively assume a maximum constant plume width with no lateral dispersion. This set of assumptions may result in unrealistically high calculated concentrations at the stock well boundary. However, the results of the upper bound analysis for Case IID demonstrate that, even if the degraded transport properties assumed here are concluded to be realistically after experimentation during the WIPP Test Phase, engineering modifications to the waste and/or backfill (that assume the same radionuclide solubility of 10^{-6}M as in Case IIA) should be able to improve performance enough to give a high confidence of compliance. The total release for the upper bound analysis in Case IID is 0.0124 times the standard. The total release calculated for the upper bound analysis for the expected Case IIA is well below the release limit (by more than a factor of a million). These results and conservative assumptions made in calculating them suggest that appropriate performance assessment methods and likely values of parameters will show that the WIPP will comply with the standard.

Thus, while these scenario calculations do not permit a full comparison with the geologic disposal standards' probabilistic release limits, even in a deterministic sense, they do suggest a likelihood of being able to show compliance when enough data are obtained to allow the required uncertainty analyses and probabilistic assessments. They also indicate the potential efficiency of engineering modifications, should the results of performance assessment prove unacceptable assuming the present waste form.

5.5 NO ACTION ALTERNATIVE

Under the No Action Alternative, TRU waste would not be shipped to the WIPP for the Test or Disposal Phases. TRU waste would continue to be generated and stored as is currently practiced at the DOE defense facilities. The following SEIS Subsections address the consequences of the No Action Alternative at the WIPP and at the four facilities for which NEPA documentation has been completed; the Idaho National Engineering Laboratory and the Rocky Flats Plant (DOE, 1980), the Hanford Reservation (DOE, 1987b), and the Savannah River Plant (DOE, 1988g).

5.5.1 Biology

Biological impacts at the WIPP from implementing a No Action alternative would be dependent upon the final status of the facility. Impacts would be similar to those identified for the proposed action if the facility were put to other uses which involved comparable levels of activities for comparable periods of time as proposed for WIPP operations.

Impacts from decommissioning and dismantling the facility would be similar to those described in the 1980 FEIS for the proposed action. Plants and animals in the area would be affected by fugitive dust, noise, and road traffic. Disturbed land would ultimately return to its natural state.

5.5.2 Socioeconomics

Decommissioning and dismantling the facility under this alternative would cost, in addition to the approximate $850 million spent through the end of FY 1989, up to $400 million over the period for facility closure (estimated to be five years). During this period, backfill for the mined areas, building razing, restoration of the site surface, and other closure activities associated with the physical location would occur. Operating contractor and DOE personnel would exit the area over the period.

In effect, the No Action Alternative would have a detrimental impact on southeastern New Mexico—particularly on Eddy County and mainly on the City of Carlsbad. During FY 1988, the jobs created or supported by the WIPP project were estimated at over 1800 in the two county region or 4.6 percent of the total regional employment (Adcock et al., 1989). Total economic activity was estimated at nearly $210 million and the annual addition to personal income at $50 million. The current level of activity (FY 1989) is approximately the same. With the No Action Alternative, these conditions would begin a downward trend in FY 1990.

Under the Proposed Action, the jobs impact in the region would have leveled at just over 1600, with total economic activity at slightly above $160 million annually (constant 1990 dollars). The annual personal income addition caused by the WIPP Project would have been about $43 million (constant 1990 dollars).

Under the No Action alternative, the regional economy would cease to receive these positive impacts by the end of FY 1994 rather than at the end of the decommissioning in FY 2018. The No Action alternative would cause community-based economic concerns at a time when the region is suffering from decreased activity in potash mining and oil and gas production. The City of Carlsbad and its environs would bear the greatest proportion of the regional loss of economic activity. Over the 24-year period, from the beginning of FY 1995 through decommissioning in FY 2018, total personal income would have increased $960 million under the Proposed Action. During the same time period, WIPP-related additional economic activity (indirect spending) would have been $3.6 billion in the region.

If the No Action alternative were chosen, after facility closure by the end of FY 1994, over $1.2 billion of federal monies would have been expended on planning, preconstruction, construction, preoperation, experimental activities, mitigation, and expenses for the closure of the WIPP.

Additional costs and risks will occur at generators and storage facilities proposing to ship wastes to the WIPP. Presently, there is not an estimate for the additional cost associated with not disposing of the wastes as planned. Under the No Action Alternative, the costs for maintaining these wastes in a non-permanent mode until an alternative to the WIPP becomes operational would add to the costs already incurred by the DOE.

5.5.3 Land Use

Implementing the No Action Alternative would return the currently controlled lands to their previous status. Existing mineral denials would once again be available for commercialization. A minor increase in grazing allotments on public lands would accrue to this alternative (approximately 18 cattle).

5.5.4 Air Quality

Implementing the No Action Alternative would result in temporary decline of air quality (principally TSP) due to dismantling activities. These impacts would be small and would not have long-term implications. The impacts would be similar to those that could occur during decommissioning of the WIPP in the Proposed Action.

5.5.5 Cultural Resources

Impacts from implementing the No Action Alternative would be the same as for the Proposed Action. Special precautions would be taken to preserve cultural resources.

5.5.6 Water Quality

No impacts would occur to the hydrology and water quality at the WIPP site from implementing the No Action Alternative. All excavated drifts and shafts would be backfilled.

5.5.7 **Transportation**

If the No Action Alternative was selected, there would be no transportation risk from transportation of CH TRU or RH TRU waste to the WIPP. Shipment of TRU waste to interim storage facilities would continue.

5.5.8 **Radiological Assessment**

For the No Action Alternative, TRU wastes would not be emplaced at the WIPP. Therefore, there would be no radiological consequences to workers or the public at the WIPP site. If the No Action Alternative was selected, routine exposures would continue to occur at the interim storage facilities.

Some of the major interim storage facilities have completed NEPA documents which describe not only the effects of continued interim storage, but also the modification options which could be employed to enable the use of their current interim storage facilities for indeterminate periods of time. The following subsections provide a synopsis of the routine exposures expected at current interim storage sites if no action were taken to open the WIPP. This subsection describes exposures and facility modifications which would generally be representative of those expected at all interim storage facilities under the No Action Alternative. The reader is referred to the published environmental documents for greater detail: DOE (1988g), DOE (1987), and DOE (1980).

5.5.8.1 **Radiological Impacts - Idaho National Engineering Laboratory**

The impacts at the Idaho National Engineering Laboratory of not opening the WIPP are addressed in the FEIS (DOE, 1980). TRU waste presently stored in a retrievable fashion at the Idaho National Engineering Laboratory would remain in surface storage for an indeterminate period or be transferred to another storage facility. Waste could continue to be shipped to Idaho National Engineering Laboratory from other DOE facilities and held in storage throughout the same indeterminate period. Methods for managing waste under this alternative were considered in detail in Appendix N of the FEIS, and are summarized below.

Subalternative 1: Leave the waste in place, as is. A cover of plywood, polyvinyl sheeting, and three feet of earth would be maintained over the waste. Monitoring and sampling would continue. Additional waste received would be similarly stored.

Subalternative 2: Improve in-place confinement of stored waste. The confinement of the waste would be improved without relocation. Providing a barrier over the top and sides of the waste would consist of adding ten feet of compacted clay and a 3-foot cover of basalt rip-rap over the storage pads. Barriers at the bottom of the waste would include the same clay and basalt rip-rap as on top and would add a pressure-grout sealing of the sediments beneath the asphalt pad. Alternately, the waste would be immobilized in place by injecting grout into the waste and into the sediments beneath the pad.

Subalternative 3: Retrieve, process, and dispose of the waste at the Idaho National Engineering Laboratory. The stored TRU waste would be retrieved from its present location, processed, and shipped to a disposal facility elsewhere at the Idaho National Engineering Laboratory. Retrieval would be achieved using a mobile, single-walled structure, with pressure control and filters, erected over the pad. Waste would be transported by truck to a processing building. Three methods of processing were discussed: 1) incineration by slagging pyrolysis, 2) compaction, immobilization, and packaging, and 3) repackaging only. The waste would then be transported by truck for on-site disposal. Four on-site disposal methods were discussed: 1) a deep-rock vault with shaft access, with the shafts eventually filled with rock and concrete, 2) a deep rock vault with tunnel access, 3) engineered shallow burial in lacustrine sediments, and 4) an engineered surface facility near the Radioactive Waste Management Complex at Idaho National Engineering Laboratory. At this location soil is 15-feet thick over a 100-foot layer of basalt. The structures would be made of concrete, would rest on the basalt base, and would be buried. The structure would extend above ground level.

The FEIS concluded on the basis of its risk analysis that the first two subalternatives would result in limited radiation releases in the short term and concluded that only very small releases would result in the third subalternative from either routine operation or accidents. The FEIS concluded that no environmental reasons were found why TRU waste could not be stored at the Idaho National Engineering Laboratory as it is presently for several decades or a century.

The 1980 FEIS, which concentrated on the impacts of long-term storage of TRU waste at Idaho National Engineering Laboratory, evaluated projected accidental releases and exposures from human-caused events and natural disasters, as a result of no action or leaving waste in interim storage. The FEIS evaluated the impacts (radiological) of disruptive natural events of volcanic action, earthquake, dam failure, and human intrusion. The summary of dose commitments presented in the FEIS (1980) are summarized in Table 5.66.

The FEIS concluded that volcanic activity holds the greatest potential risk for long-term accidental release of radionuclides, under "as is" conditions and under "improved confinement.' The improved confinement option involved providing a barrier of 10 feet of clay and 3 feet of basalt rip-rap over the waste, as well as injecting grout into the waste and the sediments beneath the supporting asphalt pad. The conclusions of the FEIS regarding volcanic activity and its impact on the nearby population as a result of long-term storage are summarized in the following paragraphs (FEIS Appendix N should be consulted for further details).

TABLE 5.66 Summary of long-term dose commitments for leaving the stored waste in place at INEL, without additional mitigation measures[a]

Disruptive event	Whole body	Bone	Lung
Maximum individual[b] 50-year dose commitment (rem)			
Explosive volcano	6×10^{-3}	8	20
Earthquake	2×10^{-8}	2×10^{-5}	4×10^{-5}
Mackay Dam failure	3×10^{-9}	1×10^{-4}	NA[e]
Volcanic lava flow[c,d]	3×10^{-2}	50	90
Intrusion			
Ingestion	7	400	NA
Inhalation	10	500	700
Population[f,g] 50-year dose commitment (man-rem)			
Explosive volcano	40	40,000	80,000
Earthquake	1×10^{-4}	1×10^{-1}	2×10^{-1}
Mackay Dam failure	1×10^{-8}	5×10^{-4}	NA
Volcanic lava flow[c,d]	100	200,000	400,000
Intrusion			
Ingestion	70	4,000	NA
Inhalation	90	4,000	6,000

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[a] Data from DOE (1980).

[b] The whole-body dose received from natural background radiation during the 50 years is about 7.5 rem.

[c] Overburden was assumed to resist lava flow as long as maintenance continued. Release was assumed to occur 100 years after implementation, when maintenance has been discounted.

[d] The dose-commitment calculations for this scenario are subject to large uncertainties.

[e] NA = not applicable.

[f] Population = 130,000 except for intrusion, where it is 10.

[g] The whole-body population dose received from the natural background radiation during the 50 years would be about 1,000,000 man-rem for the larger population and about 75 man-rem for the population affected by intrusion.

Drawn from a study of many possible release mechanisms (DOE, 1979a), Table 5.67 gives estimates of the possible radiation doses resulting from these disruptions. Natural disasters could deliver significant dose commitments (up to 90 rem to the lung) to maximally exposed individuals if the first subalternative were used; the second subalternative would reduce this dose commitment to 0.9 rem. Human intrusion could deliver much higher dose commitments to a few people. Improved confinement (subalternative 2) gives the possibility of a hundredfold-smaller individual and population dose commitments, but leaves the waste at the surface.

In summary, no environmental reasons have been found why TRU waste could not be left at the Idaho National Engineering Laboratory stored as it is for several decades or even a century; over such a time volcanic activity is unlikely, and government control of the site will prevent inadvertent human intrusion. In the long term, however, volcanic action that could produce large exposures to radiation is possible.

5.5.8.2 Radiological Impacts - Savannah River Plant

An Environmental Assessment (DOE, 1988g) was prepared which discussed the programmatic impacts at the Savannah River Plant of the WIPP not opening (No Action Alternative). It was determined that the Savannah River Plant would continue interim storage of retrievable and newly-generated TRU waste on storage pads. The waste is contained in concrete and steel boxes, culverts, and drums. Packages placed in interim storage on concrete pads were covered with four feet of soil until mid-1985; currently, they are covered with tornado netting. Based on current processing rates, one additional storage pad would be needed each year until an environmentally acceptable long-term disposal option is found. Corrosion of drums after several years of storage, and subsequent contamination of the environment is possible. This alternative does not provide for the permanent disposal of TRU waste nor allow the Savannah River Plant burial grounds to be closed according to DOE directives issued in the June 1983 Defense Waste Management Plan.

Table 5.68 provides a summary of consequences from postulated accidents at the Savannah River Plant Burial Grounds. This information illustrates the potential exposures to on-site and off-site populations from leaving TRU waste in retrievable storage.

5.5.8.3 Radiological Impacts - Hanford Reservation

An FEIS was prepared in 1987 which addressed the impacts at the Hanford Reservation of not opening the WIPP (DOE, 1987); the continued storage of radioactive TRU wastes was evaluated as Alternative 4. This alternative was similar to the In-Place Stabilization and the Disposal Alternative except that sites would not be stabilized unless subsidence was detected, and TRU sites would not be covered with a protective barrier and marker system.

For the No Action Alternative, retrievably-stored and newly-generated TRU waste would continue to be retrievably stored for 20 years after generation; current packaging and storage procedures would be followed. The drums would be stored in designated TRU waste sites and covered with soil. After 20 years it might be reclassified as buried

TABLE 5.67 Possible long-term consequences of storage at INEL

	Individual dose commitment (rem)			Population[a] dose commitment (man-rem)		
Release mechanism	Whole body	Bone	Lung	Whole body	Bone	Lung
Subalternative 1: Waste left as is[b]						
Volcano	0.006	8	20	40	40,000	80,000
Lava flow	0.03	50	90	100	200,000	400,000
Intrusion[c]	10	500	700	90	4,000	6,000
Subalternative 2: Improved confinement[d]						
Volcano	0.00006	0.08	0.2	0.4	400	800
Lava flow	0.0003	0.5	0.9	1	2,000	4,000
intrusion[c]	0.1	5	7	0.9	40	60

[a] Population is 130,000 for volcanic action and lava flow, 10 for human intrusion.

[b] Data from Table N-1 in Appendix N (FEIS, 1980).

[c] Dose from inhalation.

[d] Data from Table N-2 in Appendix N (FEIS, 1980).

TABLE 5.68 Summary of consequences from postulated accidents in the Savannah River Plant Burial Ground[a]

Accident	Curies Released	Effective Dose Equivalent On-site Population (person-rem)	Off-site Population (person-rem)	Offsite Maximum Individual (mrem)
Winds				
100 mph[b]	2.1×10^{-2}	1.6×10^{-1}	4.4×10^{0}	6.3×10^{-2}
> 150 mph[b]	4.2×10^{-2}	2.2×10^{-1}	6.3×10^{0}	7.3×10^{-2}
Tornado				
113-157 mph	2.5×10^{-2}	9.3×10^{0}	$1.6\times10^{+1}$	1.3×10^{-2}
158-206 mph	5.3×10^{-2}	$2.1\times10^{+1}$	$3.5\times10^{+1}$	2.7×10^{0}
Fire				
Drum in culvert	1.7×10^{0}	$9.3\times10^{+3}$	$2.0\times10^{+4}$	$4.4\times10^{+3}$
Drum on TRU pad	5.0×10^{-3}	$2.8\times10^{+1}$	$6.1\times10^{+1}$	$1.3\times10^{+1}$
Drum Rupture				
Internally induced	5.0×10^{-3}	$2.8\times10^{+1}$	$6.1\times10^{+1}$	$1.3\times10^{+1}$
Externally induced	5.0×10^{-5}	2.8×10^{-1}	6.1×10^{-1}	1.3×10^{-1}

[a] Estimated from the analysis of potential Burial Ground accidents (DOE, 1988g).

[b] Straight winds.

waste. Monitoring, surveillance, and maintenance would continue until a recovery or disposal decision is made.

The estimated total-body radiation dose to the workforce at the Hanford Reservation under the No Action Alternative (continued storage) was 20 person-rem. When considering institutional controls, the off-site public would receive no radiation dose from retrievably-stored and newly-generated TRU waste. In the absence of institutional controls, however, the potential exists for adverse impacts to the off-site population because nothing would prevent intrusions into waste sites or use of contaminated groundwater. It was estimated (DOE, 1987) that potential total-body doses resulting from various human intrusion scenarios involving drilling or excavation into retrievably-stored TRU waste would range from 4×10^{-4} to 4 rem/year. The potential total-body dose to a resident living on the Hanford Reservation TRU waste storage site was estimated to be 60 rem/year.

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6.0 MITIGATION MEASURES

6.1 INTRODUCTION

As defined in the regulations issued by the Council on Environmental Quality, "mitigation" includes avoiding, minimizing, rectifying, reducing, eliminating, and compensating for adverse impacts (40 CFR Part 1508.20).

The purpose of this section is to summarize mitigation measures that have been implemented at the WIPP site, measures that are proposed, and some conceptual measures that could be applied. In addition, this section describes those mitigation measures (principally waste-treatment technologies) that could be used if information gathered during the Test Phase reveals a need for such mitigation to ensure adequate long-term performance of the repository.

The FEIS in Section 9.6 identified several design features and construction practices that were proposed to be implemented in order to mitigate the potential adverse effects of the WIPP project. These mitigation measures were primarily related to construction activities and included minimizing zones of construction activity, restoring areas disturbed by construction, diverting surface runoff from salt-pile areas, and controlling fugitive dust through the use of surfactants and paving in zones of major construction traffic.

Mitigation measures that have already been implemented are discussed in SEIS Subsection 6.2. The remaining subsections evaluate mitigating measures that, if necessary, could be implemented to minimize adverse impacts during the long-term period following the decommissioning of the repository. These include engineering modifications and waste-treatment technologies.

Engineering modifications may involve the placement of fill materials, grouting, and other activities intended to prevent the long-term movement of waste materials from their original location of emplacement. These modifications generally include the creation of physical barriers to the movement of waste materials. SEIS Subsection 6.3 describes engineering modifications that could become the standard operating procedures (SOPs) during the Disposal Phase.

Waste-treatment technologies are described in SEIS Subsection 6.4. The purpose of this subsection is to describe, in conceptual terms, the current technologies that exist to treat TRU and mixed TRU waste. The purposes of these treatments, as they relate to the WIPP, may include preparation for transportation to the WIPP in compliance with the WIPP Waste Acceptance Criteria, the TRUPACT certified waste form, and/or the modification of the waste form to ensure long-term repository performance.

It is not known which, if any, of the technologies presented in SEIS Subsections 6.3 and 6.4 may be required to ensure long-term repository performance. Decisions would be based on data generated during the Test Phase. If, for example, it were determined through the Test Phase experimentation that gas-generation is a long-term repository problem, then gas-getter materials could be selected as a mitigative measure. Other experimental results could identify the need for other treatments. Thus, these subsections are intended to describe what types of technologies currently exist for treating waste, what types of problems these technologies are intended to correct, and which technologies are currently used or proposed at other DOE facilities.

6.2 CONSTRUCTION-RELATED MITIGATION MEASURES

Since the construction of the WIPP surface facilities and access shaft is virtually complete, the following mitigation measures have already been implemented. Many of these measures were discussed in Subsection 9.6 of the FEIS.

Existing Facilities. The surface facilities, the shafts, and most of the underground waste repository have been constructed. The remaining repository area has not yet been excavated to prevent the premature closure of empty rooms by salt creep; it will be excavated as needed. The requirements of the Occupational Safety and Health Administration (OSHA) and Mining Safety and Health Administration (MSHA) have been closely followed. The existing surface facilities have been constructed with air locks and controls to create negative pressures to minimize the potential for the release of hazardous or radioactive materials during operation. High-efficency particulate air (HEPA) filters have been included in air-exhaust systems to mitigate the impact of any release that might occur during normal operations or in the event of an accident.

Biology. Ecological resources have been and will continue to be protected by avoiding unnecessary damage to vegetation, wildlife, and soil by controlling traffic, minimizing the areas of disturbance, controlling runoff, and cleaning up spills. As stated in Subsection 9.6.1 of the FEIS, temporary facilities (e.g., haul roads, stockpiles, and work areas) are restored by regrading, reseeding, and fencing as construction activities are completed. Environmental monitoring programs will continue to provide early warning if the biological environment is being affected so that mitigative measures can be developed and implemented.

To study the impacts on raptors, a Cooperative Raptor Research and Management Program was initiated jointly by the DOE, the BLM, and the Living Desert State Park in Carlsbad, New Mexico. As a result of this program, work schedules in field locations near nesting raptors have been modified and 10 man-made nest platforms have been placed around the WIPP site.

Socioeconomics. Socioeconomic impacts associated with the WIPP project have been reduced through the release of land in Control Zone IV for unconditional use. Among the mineral resources released for mining were approximately 50 million tons of potash that were unavailable under the 1980 proposed action. Additional mitigative measures for socioeconomic impacts have previously been discussed in FEIS Subsection 9.6.6 and updated in Subsection 5.1.2 of this SEIS.

Transportation. Programs have been developed to reduce the chances of accidents and the effects of any accident when transporting waste to the WIPP site. Through the States Training and Education Program, over 2,400 law-enforcement, medical, and fire personnel along the transportation routes were trained in 1988 (see SEIS Subsection 2.8). This program would continue as requested by involved government agencies.

The containers (TRUPACT-II) in which the radioactive wastes would be transported to the WIPP site have been designed to meet DOT 7A, Type B packaging requirements and are currently undergoing testing for certification by the NRC. These design requirements are specified to minimize the potential for releases in an accident.

A contract has been placed with a trucking company to transport wastes to the WIPP. The details of the contract include measures to reduce the chance of accidents, such as strict specifications for drivers and trucking equipment. The drivers are required to meet the licensing, training, and physical qualification requirements set forth in 49 CFR Parts 177.825 and 391 and the Commercial Motor Vehicle Safety Act of 1986 and subsequent amendments. In addition, each driver must be at least 25 years of age, have logged a minimum of 100,000 miles in a tractor-trailer combination, and have at least 2 years of uninterrupted commercial tractor-trailer driving experience during the last 5 years. Approved drivers would undergo a driver-training program that complies with the requirements of 49 CFR Part 177.825, including accident or other emergency training. Two drivers would be in the tractor-trailer during transport, and one driver would remain with the tractor-trailer during stops.

A sophisticated tracking and communication system (TRANSCOM) has been developed for monitoring truck movement when transporting waste to the WIPP site. This near-real-time system would operate 24 hours per day and would use navigation, telecommunication, and computer network technologies to verify that each tractor-trailer is on the specified route and following the established transportation schedule. This system is currently being tested with the drivers and trucking equipment.

Air Quality. The air pollution control measures described in Subsection 9.6.2 of the FEIS would continue throughout operation of the WIPP. Hydrocarbon emissions are being controlled through the use of proper fuels. Dust levels were reduced by paving heavy traffic areas in the summer of 1988; dust will continue to be controlled by spraying water on temporarily disturbed areas.

Cultural Resources. Since the publication of the FEIS, two archaeological investigations have been performed for the WIPP project. The first investigation located 40 archaeological sites in the area of the WIPP site, and the second investigation consisted of the excavation and evaluation of three sites that could be disturbed or destroyed by construction activities. One of the three sites would have been destroyed by constructing the railroad spur to the WIPP site, but this adverse effect was avoided by relocating the railroad spur. The locations of the archaeological sites are conducive to additional mitigation measures should WIPP activities necessitate disturbance of any of the sites.

6.3 LONG-TERM FACILITY PERFORMANCE ENGINEERING MODIFICATIONS

6.3.1 Engineering Modifications Related to Geologic Parameters

Since the FEIS was issued, geologic concerns have been raised regarding the effects of mining operations on the host rock. Excavation of underground rooms at the WIPP has resulted in fracturing of the surrounding rock, creating a "disturbed-rock zone."

The disturbed-rock zone is a volume of rock whose mechanical properties (e.g., the elastic modulus) and hydraulic properties (e.g., permeability and fluid inflow) have been changed by mining. Disturbed-rock zones may provide pathways through which fluid can bypass the seals (see also SEIS Subsection 5.4.2.4). The sizes of disturbed-rock zones at the WIPP have been characterized by three approaches: visual observation, geophysical methods, and measurement of hydraulic properties. All three approaches define a disturbed-rock zone extending laterally throughout the excavation and varying in depth from 1.0 to 5.5 yards, according to the size and age of the opening (Borns and Stormont, 1988). Two possible mitigation measures for disturbed rock zones are discussed in the following subsections.

6.3.1.1 Removal of the Disturbed-Rock Zone at Seal Locations. Two major considerations in sealing tunnels and access ways are the quality of the seal-rock interface and the nature of the disturbed-rock zone near the seal. Backstress in response to salt creep in the vicinity of the relatively rigid concrete or consolidated seals should promote the healing of fractures in the disturbed rock, thereby decreasing its permeability. However, the rates and amount of permeability reduction due to the healing process are not well known. If the disturbed-rock zone fractures are not healed by salt creep, they could interconnect the waste-disposal panels with other portions of the underground facility.

The development of disturbed-rock zones has already affected maintenance for several underground excavations. A primary concern during the Test Phase is to maintain a safe tunnel roof and rooms from which the retrieval of waste will not be impeded by rockfalls. To that end, frequent inspections, removal of loose rock, rock bolting, wire mesh, and other techniques are employed and would continue to be employed as required.

Because the healing of the disturbed-rock zone may not be fast enough, and in order to create a better match of seals to the host rock, excavation of the more transmissive portion of the disturbed-rock zone around seals in accessways is being considered. Of course, a new disturbed-rock zone would form around the newly excavated volume; however, the evidence is that disturbed rock zones grow slowly, so that if the seal is put into place quickly, the size and importance of the new disturbed-rock zone as a possible bypass would be minimal.

Excavation of the relatively permeable Marker Bed 139 (MB139) under the seals is also being considered. However, that would not eliminate leak paths around the seals through more distant parts of MB139. If MB139 is left under the tunnels, it would be grouted with a salt-based grout. Removal of MB139 rock from under the seals would not eliminate the need to grout MB139, but would merely change the location of the grouting to more distant parts of that bed.

During the Test Phase at the WIPP the DOE would continue to look for more effective means of isolating the waste disposal panels from each other and sealing the shafts to the surface.

6.3.1.2 Grouting of the Disturbed-Rock Zone Around Shafts. Excavation of the disturbed-rock zone at a proposed shaft-seal location would be operationally more difficult than in a horizontal tunnel because the rock breakout and removal would either 1) precede the emplacement of the crushed-salt seal material and hence provide more time for the disturbed rock zone to reform, or 2) the rock breakout and removal would have to proceed in parallel with the seal-material emplacement.

An alternative under these circumstances might be to pressure grout the disturbed-rock zone in the vicinity of the proposed seal. The difficulty with this technique compared with excavation is that excavation can be guided to some extent by the appearance of the rock not yet taken out; on the other hand, the depth to which the rock should be grouted would have to be guided by the ability of the disturbed rock to accept more grout.

6.3.2 Engineering Modifications Related to Hydrology and Water Quality

The FEIS considered the option of backfilling only as a means of reducing fire hazards during disposal operations (FEIS Subsection 8.4.1) and for minimizing the impacts of subsidence (FEIS Subsection 9.7.2.2). A combination of engineering modifications and geologic investigation have essentially eliminated prior concerns in these respective areas. However, studies since 1980 have raised the concern of potential brine inflow. This section addresses the questions of using alternative backfill materials at the WIPP as well as sealing possible routes through which brine could migrate from one part of the facility to another or to the shafts and upward to the Culebra water-bearing zone in the Rustler Formation or to the ground surface.

6.3.2.1 Emplacement of Backfill. The reason for backfilling WIPP disposal rooms and access tunnel systems (i.e., filling in spaces that remain open after waste has been emplaced) would be to shorten the estimated "time for closure" of the disposal room. (The time for closure is the time required for salt creep to reduce room void space and to compact the waste to a final state.) Rapid entombment is desirable to minimize the contaminant releases from an inadvertent intrusion by a drillhole. Backfilling would decrease the amount of brine inflow and thereby decrease the amount of gas generated by the corrosion of waste drums and the iron-bearing constituents of the waste.

In the FEIS, only crushed salt was considered for backfill. Since the FEIS, it has become apparent that various types of backfill may also be useful to 1) speed the entombment process and to rapidly reach final porosity within the waste areas, 2) sorb brine as it flows in, and 3) minimize the generation of gases.

Backfill materials under consideration include crushed salt or a 70:30 mixture of crushed salt and bentonite (SEIS Subsection 6.3.2.2). Crushed salt may be used for the access ways and either crushed salt or the salt-bentonite mixture for the disposal rooms. The need for additives that could be mixed with the backfill, such as "getters" that remove gases by absorption, would be studied in the Test Phase.

Backfilling would generally occur as follows: Crushed salt from concurrent mining operations or from aboveground storage would be 1) screened to remove oversized pieces, 2) mechanically mixed with bentonite and any additives, 3) transported hydraulically or by conveyor belt to the emplacement location, and 4) emplaced loosely by gravity feed. When a waste disposal panel is completely backfilled, panel seals would be constructed to isolate the panel from the rest of the repository. Backfill materials would be placed loosely; compaction of backfill to greater densities appears to be costly (requiring manual labor in constricted spaces), without much additional benefit. Variations on these procedures might include blowing the backfill material into place to increase its in-place density and to reduce the overhead space as far as irregularities in tunnel ceilings permit or using a coarse grout to fill those spaces. Any procedure that could expose workers to poorly ventilated spaces would be evaluated with consideration of worker safety.

6.3.2.2 Backfill Modifications. Current plans propose that accessways, tunnels, and waste-filled rooms be completely backfilled during the Disposal Phase to improve the entombment process (Tyler et al., 1988). However, during the Test Phase, a limited backfill operation would be conducted in a way that would mitigate impacts during retreival operations should this be necessary. This limited operation would use salt and/or additives to develop operational experience, investigate engineering modifications, and evaluate the effectiveness of different types of backfill in mitigating brine inflow and gas generation (SEIS Subsection 3.1.1.4).

Reaching steady-state conditions rapidly is important because if the contents of the room are not sufficiently dense, limited amounts of brine and water from an intruding borehole could circulate within the room, thus enhancing the outward migration of radionuclides. Erosion of regions surrounding the borehole by circulating drilling fluids could also entrain radionuclides, contributing to their release. As a mitigation measure, backfilling the waste with crushed salt may attain an acceptable equilibrium state within the repository before any potential intrusion occurs.

Sorption of brine is another function of the backfill. Although recent estimates suggest that the amount of brine inflow would be small, about 43 m^3 per room in 100 years (Nowak et al., 1988), steps to control the accumulation of brine that may come into contact with containers are being explored. Additives to crushed-salt backfill, in particular bentonite, are under consideration because of their ability to adsorb water. As already mentioned, a mixture of 70 percent crushed salt and 30 percent bentonite (by weight) is a possible backfill material. The current estimate is that between 40 and 80 m^3 of brine per room can be sorbed by the salt-bentonite mixture, without degrading its strength or imperviousness in the compacted state.

Backfill "getters" (additives that remove gas generated by bacterial decomposition, radiolysis, and corrosion) are also under consideration as potential mitigations; however, their effectiveness would be determined during the Test Phase. Additives like calcium carbonate ($CaCO_3$) and calcium oxide (CaO) are being considered for the removal of carbon dioxide (CO_2) produced by bacterial decomposition. Reduction of the microbial gas-production rate might also be accomplished by storing sludges containing nitrate (NO_3^-) apart from waste containing cellulosic materials. This option might also prevent microbial nitrogen production. The addition of manganese dioxide (MnO_2) might prevent SO_4^{-2} reduction, the concomitant production of hydrogen sulfide (H_2S), and its reaction with the drums, drum-corrosion products, and iron-bearing waste to form hydrogen. Copper sulfate ($CuSO_4$) might corrode the steel drums and the iron-bearing waste without producing hydrogen (Lappin et al., 1989). As previously stated, the effectiveness of these getters in controlling gas in the disposal rooms is a matter of continuing study in the Test Phase.

6.3.2.3 Emplacement of Plugs and Seals. The FEIS recognized the need to plug all remaining holes and shafts when the WIPP is full and is being decommissioned (FEIS Subsection 8.11.3). However, although it mentions backfilling the waste disposal rooms (FEIS Subsection 8.4.1), it does not say anything about possible tunnel seals. Current plans are still to seal all holes and shafts, in order to eliminate, as much as possible, the pathways where waste material might migrate to the overlying Culebra water-bearing zone or even the ground surface itself. The DOE also now plans a number of tunnel seals to isolate the different parts of the underground facility from each other and from the shafts (Stormont, 1988).

Tunnel Seals. Tunnels would be sealed after waste emplacement at the locations shown in Figure 6.1. The portion of the drift that is at the seal location would be filled with preconsolidated crushed salt, possibly in the form of blocks (Figure 6.2). The crushed salt would be retained by end caps, but these end caps are not expected to maintain their integrity over the long term, being there only to keep the salt in place until tunnel closure consolidates it to its final density (Stormont, 1988).

Fractures in MB139, an interbed close below the tunnel floor that is about 3 feet thick and consists primarily of anhydrite, would be filled with an anhydrite-compatible seal material such as a crushed salt-based grout, in order to keep it from being a hydraulic bypass around the seal. Thus both the tunnel and MB139 would be sealed at each seal-system location.

Seals would be emplaced after each panel of rooms or interval of access tunnels behind the specified location that has been filled with waste and backfill material. As a final action, when the WIPP is full and about to be decommissioned, tunnels outside (just north of) the final seal system would be backfilled with crushed salt until the entire underground facility, except for the shafts, has been filled. Seal systems would then be emplaced in the shafts.

Shaft Seals. Shaft-seal systems would be emplaced in each of the four WIPP shafts in order to keep these shafts from being conduits for the release of waste materials to the Culebra or the ground surface. The primary, long-term shaft seal would be a section of crushed salt or salt blocks in the lower part of the shaft. This material should be kept in its natural state of dryness, so that when it is fully consolidated as the surrounding salt closes in, its properties would be as nearly as possible those of the surrounding Salado salt. For protection of the primary seal material from seeps from above, composite seals would be emplaced midway to the top of the Salado and at the

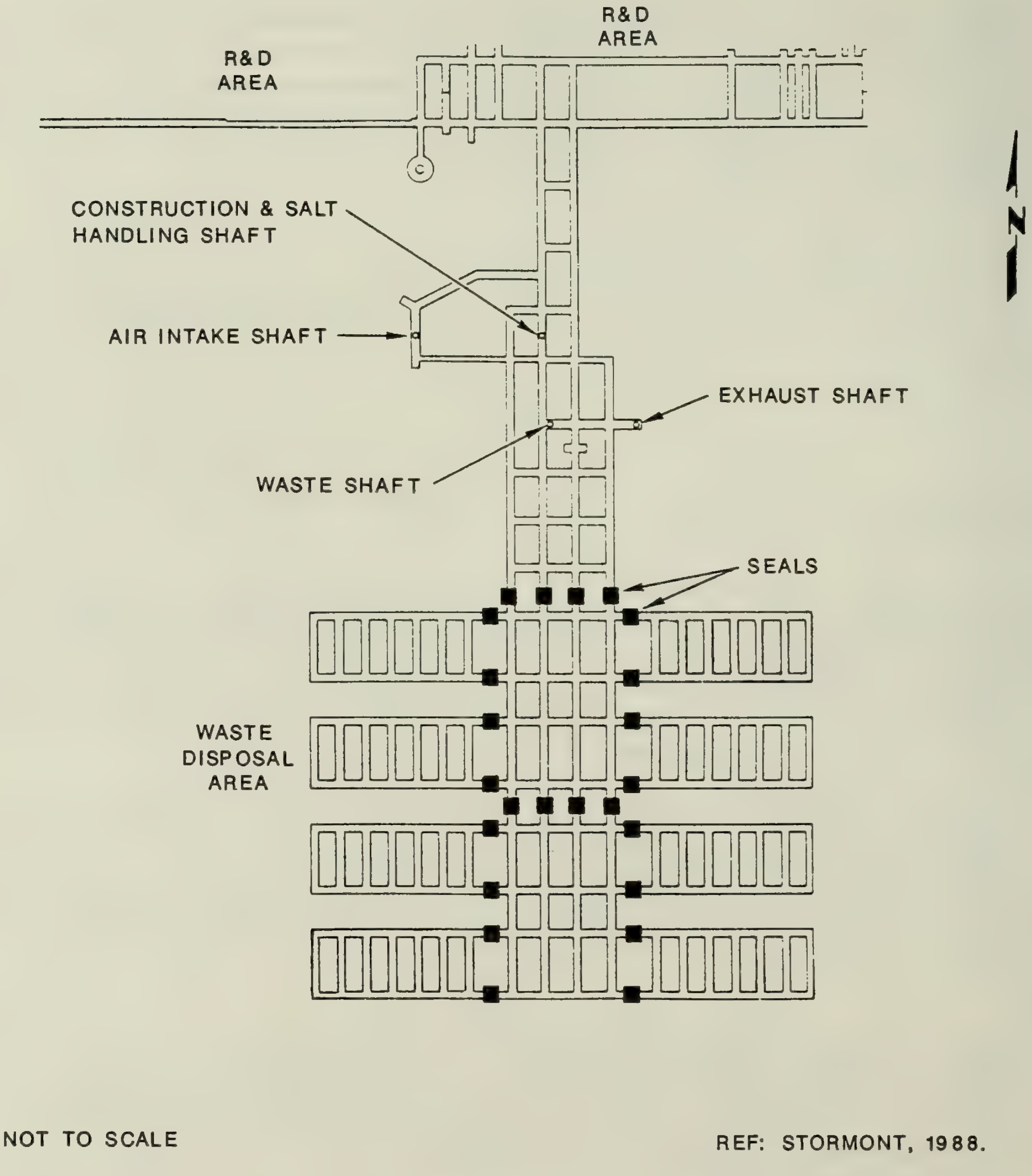


FIGURE 6.1
TENTATIVE LOCATIONS OF PANEL SEALS

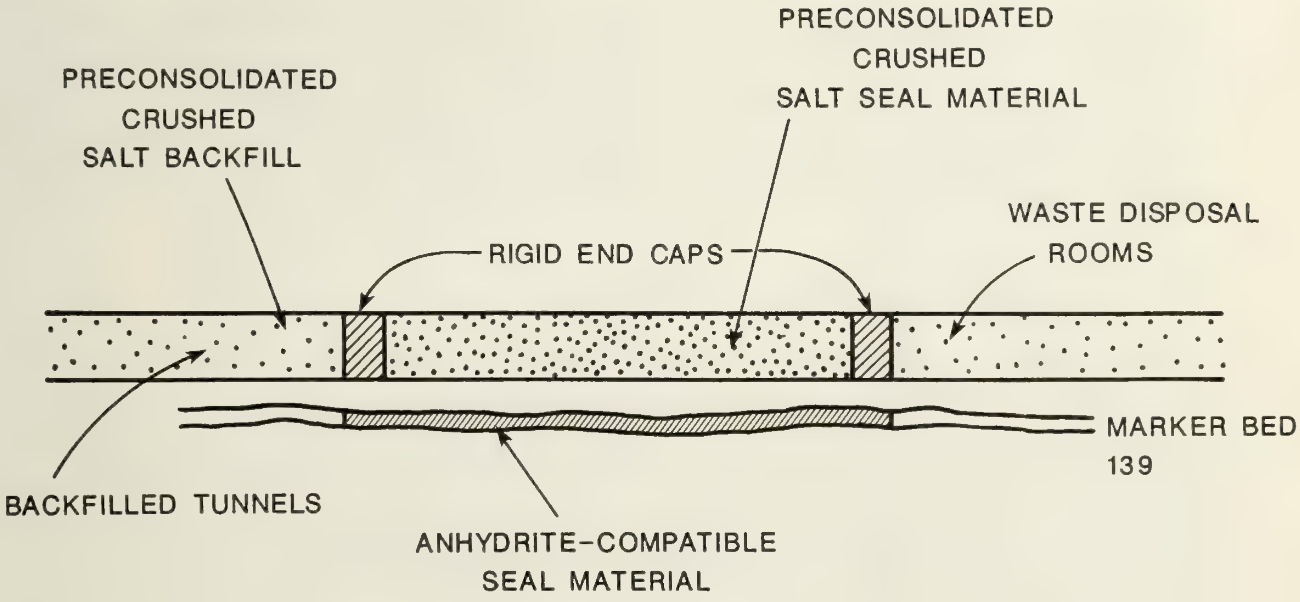


FIGURE 6.2
SCHEMATIC OF TUNNEL SEAL

Salado-Rustler interface (Figure 6.3). In addition, salt-bentonite layers would be laid where the shaft intersects anhydrite beds. All other intervals in between would be filled with salt. In the Rustler, a rather complex set of concrete and salt-bentonite sections is being considered to block off that formation's numerous water-bearing beds (Figure 6.4). These composite seals are not primary barriers, nor is the upper salt section in the Salado. Since the Rustler is at a lower lithostatic pressure, salt creep and shaft closure cannot be counted on to ensure full reconsolidation in the Rustler Formation (Stormont, 1988).

Shaft seal systems would be emplaced after the underground facility is sealed and backfilled. Emplacements would begin at the bottom of the shaft and work upward to the surface, removing the shaft liner as work progresses upward.

Variations in the shaft and tunnel seal systems are limited by the requirement of long-term effectiveness. It is for this reason that crushed salt is the primary component material in the seals described above: on reconsolidation this material should approach the properties of the in-situ rock salt. The physical form of this salt and the manner of its emplacement, however, remain open to study and future decision. The choices now evident are poured-and-tamped material or precompressed salt blocks.

6.4 MITIGATION BY WASTE TREATMENT

This subsection summarizes the development of current DOE waste-treatment technologies, emphasizing those developed since the FEIS, and discusses how various treatments (e.g., incineration, immobilization, and compaction) could provide potential benefits at the WIPP. Recent waste treatment developments in private industry are also addressed. Although the emphasis of this subsection is to identify TRU-waste-treatment technologies, information on some low-level-waste treatment systems is included to indicate that the technologies are developed to the point of use in the processing of radioactive waste, if not specifically TRU waste. SEIS Subsection 6.4.1 briefly describes the physical effects that waste treatment can provide. If during or at the conclusion of the Test Phase it was determined that additional processing would be beneficial, one or more of these technologies could be used to enhance long-term performance. The following subsections contain a qualitative discussion of the projected benefits of immobilization, incineration, and compaction.

Two general waste-treatment methods for TRU waste (incineration and immobilization) were discussed in Subsection 5.3 and Appendix F of the FEIS. Since the preparation of the FEIS, several waste-treatment systems have been developed and implemented at various DOE facilities. The installed treatment systems tend to be unique for each waste generator, because each facility has a unique mission and different waste forms. In general, however, all waste-treatment practices tend to reduce the volume and leachability of the waste. The potential need for treatment results from a combination of regulatory (frequently transportation) and disposal-site restrictions such as the WIPP Waste Acceptance Criteria (SEIS Subsection 2.4.1 and Appendix A).

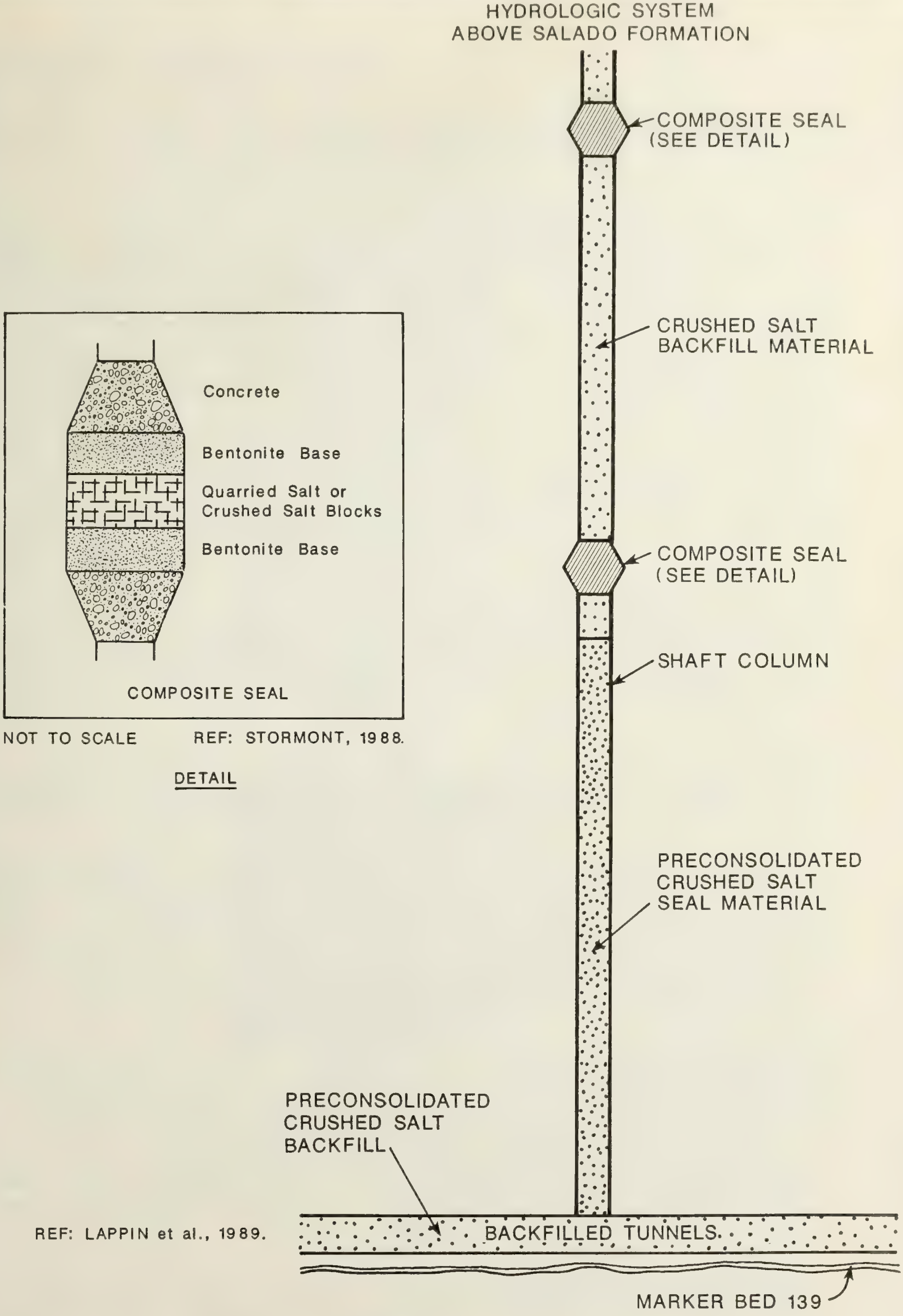
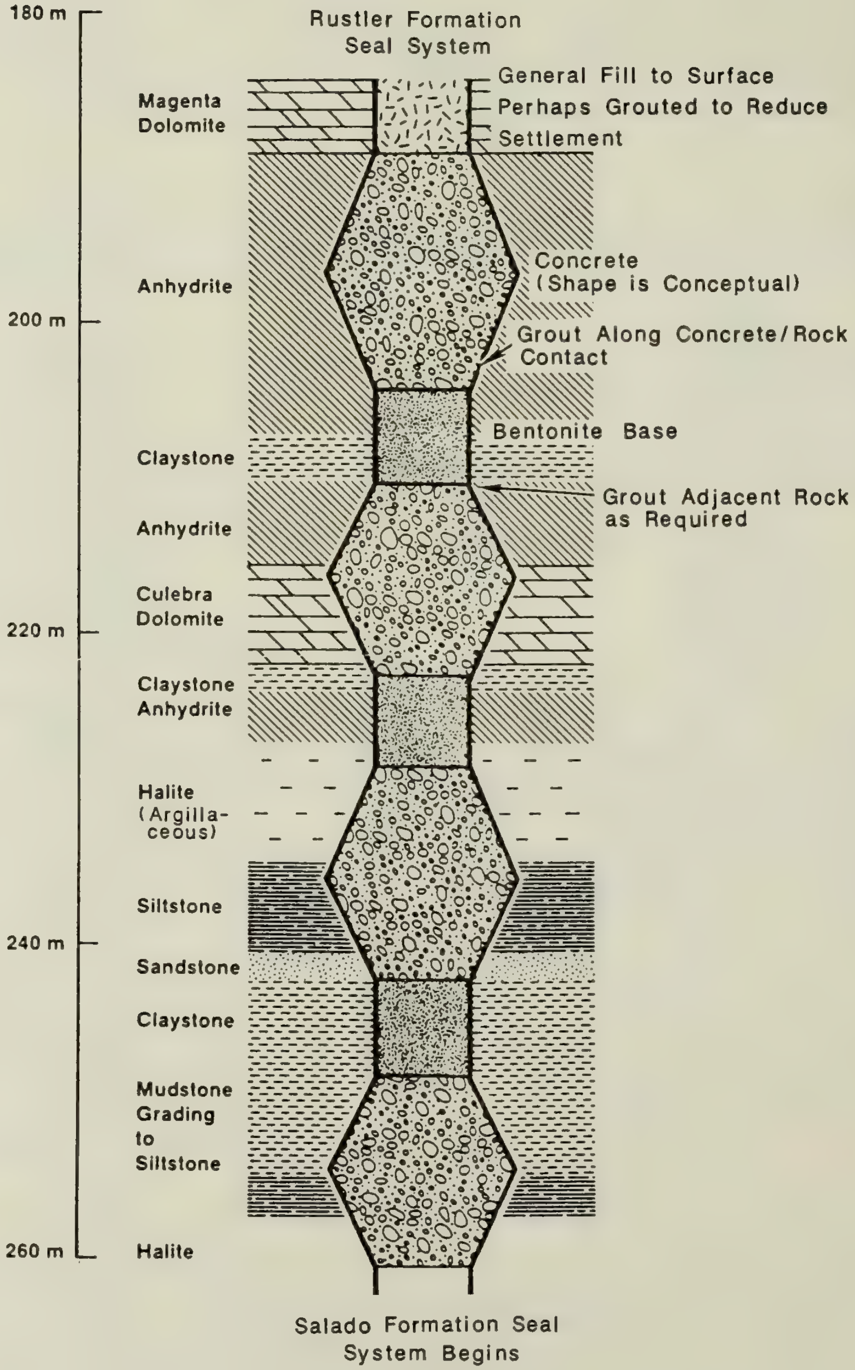


FIGURE 6.3

SCHEMATIC OF SHAFT SEAL SYSTEM IN THE SALADO FORMATION



REF: STORMONT, 1988.

FIGURE 6.4
SCHEMATIC OF SHAFT SEAL SYSTEM IN THE RUSTLER FORMATION

6.4.1 Waste-Treatment Technologies

Waste treatment influences gas generation, repository void volume, and radionuclide and heavy-metal solubility. This section discusses these three phenomena and describes how they are affected by various treatment technologies.

Wastes can generate gases by the biological (microbial) degradation of any organic materials present, by the corrosion of waste metal and containers, and by the radiation induced degradation (radiolysis) of the waste. The estimated time periods associated with these gas-generation mechanisms are discussed in SEIS Subsection 5.4. Waste forms that minimize gas generation have improved storage stability. Corrosion and biological gas generation processes at the WIPP would be dependent on the availability of oxygen and/or brine (Molecke, 1979). Therefore, any waste treatment that reduces the void space in the repository would minimize air and brine quantities and thus gas generation. Waste forms that limit the leaching of radionuclides from the waste or decrease the solubility of the radionuclides and hazardous heavy metals reduce the potential impact of brine intrusion. Soluble radionuclides and heavy metals can migrate through the brine and therefore are subject to transport with the brine. Immobilized radionuclides and heavy metals in stable waste forms remain in the waste and are not subject to brine-transport mechanisms.

The following subsections show that immobilization, incineration, and compaction all theoretically reduce gas formation and solubilities to varying degrees. However, the long-term benefits associated with these processes would be experimentally determined during the Test Phase. Specific requirements for any type of treatment would be determined on the basis of the Test Phase results.

6.4.1.1 Immobilization Technologies. Appendix F of the FEIS addressed 11 immobilization processes for treating TRU wastes. The discussion that follows updates the FEIS to reflect advances in immobilization technologies.

Bitumen (Asphalts). The mixing of particulate wastes with hot asphalt produces a solid matrix when the asphalt cools and hardens. When wet wastes are mixed with the hot asphalt, the solid particles are coated by the asphalt matrix as the water is evaporated (Kline, 1983; Mattus et al., 1988). Since 1982, this method has become more prevalent in the United States, and by 1985, it was being utilized in nine commercial power reactor plants (Jolley and Rodgers, 1987). It is not in current use at DOE facilities.

Cements and Grouts. Liquid wastes are commonly solidified by mixing with cement and grout formulations. Widely used systems for inorganic waste solidification have employed portland cement or kiln dust. Variations have consisted of such combinations as cement with fly ash, lime with fly ash, cement with sodium silicate, and lime with sodium silicate. The most popular single process has used portland cement-sodium silicate. The use of specific hydrocarbon additives allows the solidification of soils highly contaminated with oils, greases, and various other organic chemicals (Sawyer, 1988).

Radioactive mixed wastes and solid residues that have been effectively treated by cement-based immobilization include ion-exchange resins, evaporator bottoms, filter media, sludges, slags, incinerator ash, calcines, shredded metals, shredded combustibles, oils and grease, biodigester underflows, various organics, and acid-digester residues (Dole, 1985).

DOE facilities commonly use Type I portland cement for immobilization. However, this formulation is expected to be somewhat unstable in the high-sulfate brine environment of the WIPP. The Type V portland cement formulation has been shown to be much more resistant to sulfate degradation (Tuthill, 1978). TRU waste solidified with cement offers the advantage that plutonium compounds tend to remain insoluble in the resulting alkaline medium (Schneider and Lederbrink, 1982). Mobile in-drum cement-solidification systems have been successfully tested on various liquid and solid low-level and TRU wastes in the Federal Republic of Germany (Brunner and Christ, 1985). Many DOE facilities use in-drum cementing for various liquid-waste streams.

Clay. The adsorption of radioactive wastes by clays requires additional treatment to prevent desorption and leaching of the wastes. With the exception of the use of clays as a supplement to cement-immobilization systems at the Hanford Reservation Grout Treatment Facility and the Mound Tritiated Water Solidification System, clay immobilization is not presently in use at DOE facilities (Nevarez, 1988; Mills, 1989).

Pellets. The enhanced waste concentration inherent in this process was developed at the Mound Laboratory, where liquid TRU wastes were immobilized in portland cement and pressed into 1-inch-diameter pellets. Although this technology was demonstrated in 1982, no further development was done, and the plant was dismantled in 1987 (Mills, 1989).

Since immobilization does not chemically alter the organic waste, this technology is not expected to affect long-term gas generation from biological and radiolytic sources. However, it could be expected that the grout would exclude air and retard the entry of brine into the waste, thus retarding gas formation. In particular, the reduced void volume and retarded brine inflow would be expected to retard gas generation from corrosion. The high pH of cemented waste tends to reduce the solubility of radionuclides and heavy metals. Stable immobilization agents should provide the benefits of reduced void volume, reduced heavy-metal and radionuclide solubilities, and lower gas generation rates.

Plastic Materials (polymers). Organic solidification and encapsulation systems use a wide variety of "thermosetting" monomers, prepolymers, and resins that are hardened by using accelerators after mixing with liquid waste. The effect is micro encapsulation of the waste material since direct chemical interaction between the polymer and the waste does not occur. There are no known polymer solidification systems currently in operation at DOE facilities.

Salt Cake. The Savannah River Saltstone and Saltcrete operations are the sole locations where low-level-waste nitrate salts are solidified. These operations use a portland cement treatment technology (Harley, 1989; Dole, 1985).

Glass Immobilization. Vitrification involves melting particulate material with borosilicate compounds to form a glassy solid that is very resistant to leaching. Appendix F of the

FEIS discussed four immobilization techniques that involve melting of the waste: glass (solution), glass (encapsulation), ceramics, and slag. The only current activities for melted waste deal with vitrification or glassification.

The vitrification of high-level liquid wastes from fuel reprocessing has been developed at the Pacific Northwest Laboratories (Holton et al., 1988). This demonstration is of limited value to the TRU-waste-management program because the stored TRU waste and much of the newly generated TRU waste is solid. The liquid-waste-processing systems developed for the high-level-waste program have not addressed the handling problems associated with TRU-solid-waste feed.

A second application for waste vitrification has been demonstrated at the Mound Laboratory (Klingler and Armstrong, 1986). A commercial glass-melting furnace has been used to demonstrate applicability to the incineration-vitrification of low-level wastes. However, this system has encountered handling problems. Vitrification technology is not considered adequately developed for current application specifically to TRU waste.

6.4.1.2 Incineration Technologies. The incineration of radioactive waste was practiced as early as 1949 for the purpose of reducing the volume of the very low-level, combustible trash resulting from the operation of radioactive material handling systems. Later, other incinerators were built to separate the combustible material from wastes contaminated with fissionable isotopes and thereby facilitate the recovery of these valuable materials. Operationally, incineration burns off the combustible constituents of the waste (e.g., cotton, wood, and plastic), leaving an inorganic ash. Since very few radioactive isotopes of concern are volatile, the radioactivity is concentrated in the ash. In an ash form, the concentrated radioactivity is much easier to immobilize.

Incineration is generally understood to be an effective, but costly, volume-reduction treatment for waste. A cost study of volume reduction at a nuclear power station estimated the cost of a waste compactor to be $275,000 (1988 dollars), while a comparable incinerator for the application was estimated to cost $10.95 million (1988 dollars) (Trigilio, 1988). In that study, the compactor was estimated to reduce waste volumes by a factor of 2 and the incinerator reduced volumes by a factor of 16.

Radioactive waste incinerators use the same technology as trash and hazardous waste incinerators. The waste is injected into a hot chamber, where oxygen is added at a controlled rate to create a hot oxidizing environment. In this hot environment, the combustible materials are oxidized to gaseous products, mostly carbon dioxide and water. The offgas-cleanup systems on radioactive waste incinerators are very different from those of the other technologies. Multiple, highly efficient, and redundant components in the offgas system prevent the particulate (nonvolatile radioactive) material from being carried out of the stack with the combustion gases. In addition, the operators of radioactive waste incinerators take additional precautions to keep dust and ash contained in the system.

Since the preparation of the FEIS, there has been considerable activity in radioactive waste incineration. The effect has been the development and subsequent abandonment of several incineration concepts and the application and production-scale use of others.

Recognition of the hazardous chemical constituents of radioactive mixed waste has caused the operators of existing and proposed incinerators to also consider that aspect of the waste. The EPA has designated incineration as the "best demonstrated available technology" (BDAT) for certain chlorinated solvent wastes. Some of these constituents are contaminants in wastes that may be disposed at the WIPP. Acid digestion, the agitated hearth incinerator, the cyclone drum incinerator, the molten-salt incinerator, and slagging-pyrolysis incineration have not found acceptance in the waste management industry.

Controlled-air incinerators, however, have found acceptance in the industry. Several controlled-air systems for low-level waste have been installed at DOE and commercial facilities (McFee and Gillins, 1986; Farinoso and Wilson, 1983; Francis, 1988). In addition, as discussed in SEIS Subsection 5.2.1, the experimental rotary-kiln incinerator in the PREPP facility at the Idaho National Engineering Laboratory is being evaluated for the treatment of stored TRU waste that does not met the WIPP criteria (McFee and Gale, 1988). Incineration capacity is also proposed at the Los Alamos, Lawrence Livermore, and the Oak Ridge National Laboratories; the Savannah River Plant; and the DOE Pantex facility (Janowiecki, 1988; Williams and Charlesworth, 1988; Vavruska, 1989; Friedline, 1988; Starr, 1989; Stockton and Burkhard, 1988). A literature and telephone survey of radioactive waste incinerators showed that approximately 80 incinerators have been operated internationally.

The potential benefits of incinerating TRU waste include the following:

- Volume reduction. The combustible fraction of the waste would be reduced to a small fraction of the original volume, resulting in improved space utilization and reduced transportation requirements. The benefit of the reduced waste disposal space would be a reduced probability that the waste in the repository would be intercepted in an intrusion scenario. Another benefit of volume reduction would be reduced transportation costs.

- Destruction of organics. Hazardous organic constituents would be destroyed before emplacement.

- Reduced gas generation. Gas generation from the biological degradation of cellulosic materials would be eliminated. The gas generation from radiolysis would be reduced because of the removal of some gas-generating constituents. The reduced void volume and the reduced number of waste drums would lead to reduced gas generation from corrosion.

- Reduced repository void volume. Waste processed through incinerators and subsequently solidified would have a very low void fraction. Combustible material would be removed, and noncombustible fractions would be encapsulated in the resulting grout.

- Leach resistance. The immobilized incinerator ash would be leach resistant. However, oxidation of the metallic compounds would tend to convert them to a more soluble form, which is an undesirable characteristic.

6.4.1.3 Compaction Technologies. Compaction or supercompaction is a method of volume reduction that can be applied to compressible waste and that results in several benefits: 1) completely automated and isolated operation, 2) a waste form with a smaller surface area for leaching, 3) a significant reduction in internal voids, and 4) space savings in disposal. An evaluation of this technology at the Rocky Flats Plant gave projected volume-reduction factors (original volume divided by final volume) of between 2.6 for metals and 6.8 for combustibles (Barthel, 1988).

At the Idaho National Engineering Laboratory, the Waste Experimental Reduction Facility (WERF) operates a 200-ton box compactor limited to dry radioactive waste. A proposal is being evaluated for possible future addition of a 5,000-ton supercompactor at the Idaho National Engineering Laboratory (Gillins and Larsen, 1987). At the Rocky Flats Plant, a Supercompaction and Repackaging Facility (SRF) is due to start up in the spring of 1990. That facility, being prepared to support waste-volume-reduction efforts, will include a 2,200-ton drum super-compactor (Barthel, 1988). Although unrelated to the WIPP, a 1,000-ton supercompactor at West Valley, New York, is utilized for bulky items like wood, pipe, metallic scrap, and concrete rubble (Frank et al., 1988). A mid-1985 survey of commercial nuclear power plants revealed that 74 compactors were in operation (Jolley and Rodgers, 1987).

Compaction would have the benefit of void-volume reduction, resulting in less time for repository closure to the final state. This could result in retarded rates of biological and corrosion-induced gas generation. The reduced surface area of this waste form should also retard the dissolution rate of the waste; however, the compressed waste would concentrate radioactive particles and might be expected to increase gas generation by radiolysis.

6.4.2 **Effects of Waste Treatment**

Several DOE facilities are evaluating waste treatments for a number of site-specific reasons. During the WIPP Test Phase, the DOE would determine whether the mitigation measures of waste treatment should be proposed as requirements for disposal of waste at the WIPP. Qualitatively, the benefits of the improved waste forms are summarized in Table 6.1. This table shows waste treatment to provide mitigative effects, although some technologies provide greater benefits than others.

A scenario discussed in SEIS Subsection 5.4 postulates a release of material from the WIPP due to inadvertent drilling through the emplaced waste while seeking oil or gas. Waste treatment would reduce the consequences of the intrusion. If the waste is immobilized in long-lived agents, the availability of radionuclides and hazardous chemicals would be substantially reduced, resulting in a smaller release. While gas generation from immobilized waste would be retarded, it is not currently possible to qualitatively estimate any long-term benefit from this treatment.

TABLE 6.1 Summary qualitative description of waste-treatment benefits

	Waste-treatment method and benefits			
Waste storage characteristics	Immobilization of sludges or grouting of sludges	Incineration with ash immobilization	Compaction	Comments
Radiolytic gas generation	Increases gases from solidification agent (small effect)[b]	Eliminates radiolysis of organics[a] Increases gases from solidification agent (small effect)[b]	Increases gas due to compacted form[b]	
Biological gas generation	Retards generation by limiting brine and oxygen access[a]	Eliminates organic degradation[a]	Retards generation by limiting brine and oxygen access[a]	
Corrosion gas generation	Retards generation by limiting brine and oxygen access[a]	Retards generation by limiting brine and oxygen access[a] Reduces generation by reducing the number of waste drums[a]	Retards generation by limiting brine and oxygen access[a] Increases generation by adding overpack drums[b]	
Void volume	Reduces void volume by filling voids with grout[a]	Reduces voids because of cemented ash[a]	Reduces voids by compaction[a]	Reduced void volume reduces gas generation
Radionuclide and heavy-metal solubility	Retards dissolution by limiting brine access[a] Reduces solubility in alkaline medium[a]	Retards dissolution by limiting brine access[a] Reduces solubility in alkaline medium[a] Increases solubility from high oxidation state[b]	Retards dissolution by limiting brine access[a]	
Other effects	Retards dissolution of hazardous organics by limiting brine access[a]	Eliminates hazardous organics prior to emplacement[a] The reduced volume makes room penetration less likely[a]	Retards dissolution of hazardous organics by limiting brine access[a]	Hazardous-organics release is dependent on degree of immobilization and effects of biological degradation

[a] Results in improved long-term waste immobilization.

[b] Results in degraded long-term waste immobilization.

If the waste were incinerated, there are three possible effects:

1) Gas generation from the biological decomposition of cellulosic materials would not occur. The biological gas-generation potential is estimated to be somewhat less than half of the total gas-generation potential, which includes gas generation from radiolysis and corrosion. The long-term benefit of the reduced gas generation would be studied during the Test Phase.

2) Treatment of the waste by incineration includes immobilization of the ash. The resulting mitigative effects are then the same as for immobilization of the waste without incineration with the added benefit of removing organic materials and compounds.

3) Hazardous organic chemicals would not be released because they would have been oxidized and destroyed.

If the waste were compacted before emplacement, the reduced-void-volume effect would be expected to retard the formation of gases from biological and corrosion processes because the inflow of brine would be reduced, although this is difficult to predict for the long term.

Immobilization, incineration, and compaction all retard gas generation in the repository, although the long-term benefit of this effect has not yet been determined. Immobilization of the waste reduces the severity of the intrusion scenarios by decreasing the dissolution of the radionuclides and hazardous heavy metals. However, since the lifetime of the immobilization agents is unknown, the long-term benefits are also unknown.

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7.0 UNAVOIDABLE ADVERSE IMPACTS

The unavoidable adverse impacts accruing to the WIPP project have not changed substantially from those envisioned in Section 10 of the FEIS (DOE, 1980). This subsection identifies the changes in the unavoidable adverse impacts of the WIPP project that would result from changes in the Proposed Action since 1980.

7.1 CONSTRUCTION

There have been some minor changes in the unavoidable adverse impacts associated with construction activities at the WIPP site in southeastern New Mexico since the issuance of the FEIS in 1980. These changes were made primarily as a result of an effort by the DOE to modify and simplify the scope of the WIPP facilities in an attempt to reduce construction costs. This cost-reduction program was developed in 1982. Another modification proposed since the 1980 FEIS, but not yet implemented, was the upgrade of site security facilities. The impacts of this change are also discussed here as a change since the issuance of the FEIS.

7.1.1 Upgrade of Site Security Facilities

The area that comprises the currently fenced security area at the WIPP site encompasses approximately 250 acres. The DOE is proposing to expand this secured area to 1454 acres. As a result, the grazing of domesticated animals would be prohibited within this increased area. The maximum number of cattle that could be affected by the increased grazing exclusion is estimated to be approximately 18 in any one year. This impact would continue until the WIPP site is decommissioned.

The surface soils would be affected during the construction of the fences. By following recommended fence-installation procedures, this impact would be minimized. When the fences are in place and grazing has been prohibited, the vegetation normally used for forage will survive and provide some measure of stability to the soil.

During the construction of the fences, air quality may be affected from the clearing of land and from the use of construction equipment, which generates air pollutants. These types of impacts were considered in the FEIS and found not to be significant for the construction of the WIPP surface facilities. In comparison, the security upgrade construction is very minor.

7	7-1	last ¶,	In the fourth line, "Movement across the fence by deer, antelope, and javelina is possible," should read, "Movement across the fence by deer and antelope is possible."	ered ified tical No

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The surface soils would be affected during the construction of the fences. By following recommended fence-installation procedures, this impact would be minimized. When the fences are in place and grazing has been prohibited, the vegetation normally used for forage will survive and provide some measure of stability to the soil.

During the construction of the fences, air quality may be affected from the clearing of land and from the use of construction equipment, which generates air pollutants. These types of impacts were considered in the FEIS and found not to be significant for the construction of the WIPP surface facilities. In comparison, the security upgrade construction is very minor.

As described in Subsection 7.1.2 of the FEIS, there are no threatened or endangered animal species in the expanded security area. Endangered species have been identified in the WIPP vicinity; however, the expanded security area does not contain their critical habitat. Movement across the fence by deer, antelope, and javelina is possible. No effects on wildlife would be expected.

Appendix H.1 of the FEIS identified three major areas of archaeological site concentrations that were located at the WIPP site. None of the sites was judged to be significant or eligible for nomination to the National Register of Historic Places. Although no mitigation is necessary, construction crews will be closely supervised during installation of the fence so that nearby sites will not be inadvertently disturbed.

7.1.2 Cost-Reduction Program

The cost-reduction program of 1982 led to the combination and elimination of buildings, modification of the aboveground salt-handling logistics, and the reduction in overall site features. The combination and elimination of buildings and reduction of overall site features reduced effects on the terrain by reducing the amount of caliche and cut-and-fill material that would have been required.

Modification of the aboveground salt-handling logistics resulted in the creation of two waste-rock piles instead of one. The revised design includes the pile created during the Site and Preliminary Design Validation Program. A second pile was created during full-facility construction and continues to receive waste rock.

Combining and eliminating buildings and reducing the area occupied by the facilities reduced adverse impacts on site vegetation. About 80 acres that would have been cleared under the original design remain undisturbed. However, the creation of a second waste-rock pile had some adverse impacts on vegetation. Although the total volume of waste rock (mainly salt) to be stored on the surface was decreased, the dispersion of salt and other mined-rock particles will probably affect a larger area. In addition, the amount of soil sterilized by surface storage of the waste rock will not be significantly reduced. However, soils will be sterilized at two separate locations instead of one. Subsection 5.1.1 of the SEIS discusses the expected impacts of the waste-rock piles on vegetation.

The reduction in size of the overall site features reduced the magnitude of adverse impacts on wildlife. However, the use of trucks to transport the waste rock on the surface, instead of a conveyor system, increased noise levels and caused increased disturbance of avian and faunal species locally. Subsection 5.1.1 of the SEIS discusses the expected impacts on wildlife from both the past construction and the proposed operation of the WIPP.

Under the current design for the WIPP, 1454 acres will be excluded from domestic-animal grazing by fencing and used as a secured area. This is an increase above the 250 acres proposed in the 1980 FEIS and currently enclosed by fence.

The two-county population increases predicted in the FEIS were reduced by the cost-reduction plan. The total population change for the operations period was an increase of about 700 persons instead of the 1000-person increase predicted in the FEIS. This reduction resulted in fewer demands on existing community services and community resources. A discussion of the socioeconomic impacts of both the past construction and the proposed operation of the WIPP is presented in Subsection 5.1.2 of the SEIS.

7.2 **OPERATION**

The expected unavoidable adverse impacts of operating the WIPP at the Los Medanos site in southeastern New Mexico have changed little since the issuance of the FEIS in 1980. The only areas where changes have occurred result from an effort to simplify and reduce the scope of the WIPP in order to reduce costs and an effort to upgrade site security. The following paragraphs describe the impacts of these changes during the Disposal Phase at the WIPP.

During the Disposal Phase of the WIPP project, 1454 acres of land will remain unavailable for grazing. The impact of this removal is discussed in Subsection 7.1 of the SEIS. Grazing by approximately 18 cattle will be precluded during the Test and Disposal Phases.

The waste-rock pile created during full-facility construction will grow and become a more obvious feature of the landscape as additional waste rooms are mined in advance of waste emplacement. The pile will ultimately cover about 12 acres to a maximum height of about 75 feet. The waste-rock pile from the Site and Preliminary Design Validation program covers 8 acres to a maximum height of about 25 feet. Rain falling on the waste-rock piles will continue to dissolve some salt and will sterilize the soil under the pile and in the surrounding berm. Dispersion of the salt and other mined-rock particulates by wind may cause minor adverse impacts on the biota. A discussion of these impacts is presented in Subsection 5.1.1 of the SEIS. Subsection 6.2 of the SEIS provides a discussion of measures that have been implemented since the issuance of the FEIS to help mitigate the potential adverse impacts of the WIPP project.

The development of the site and facilities may potentially hinder or deny the future recovery of hydrocarbon and mineral resources. However, by allowing resource-recovery in Control Zone IV (as a result of its unconditional release back to public use) of the WIPP-site, the economic impacts will be reduced. Potential mineral resources at the Los Medanos site have been investigated. Of the mineral resources expected to occur beneath the site, five are of practical concern: the potassium salts sylvite and langbeinite which occur in strata above the potential repository level, and the hydrocarbons crude oil, natural gas, and distillate, which occur in strata below the possible repository level. Nearly three-fourths of the langbeinite reserves (the most significant potash mineral within the site) and over two-thirds of the total potash reserves would become available. Solution mining would not be permitted. However, this restriction is not expected to be significant since solution mining for langbeinite is ineffective and no such mining techniques for sylvite are currently used in the Carlsbad potash district. More than half the hydrocarbons within the site can be recovered by vertical drilling in Control Zone IV, and the rest of the hydrocarbons underlying the WIPP site may be available by directional drilling from Control Zone IV. To ensure that the integrity of the underground storage facility is protected, resource recovery

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Operation of the WIPP would release some radioactivity. The estimated committed effective dose equivalent would be about 0.07 mrem (about 0.07 percent of annual natural background radiation) for a hypothetical individual living at the point of maximum air concentration beyond the WIPP boundary. The transportation of TRU wastes to the WIPP would expose people near the transportation routes to radiation. A hypothetical person living near the highway or railroad as every waste shipment passes could receive a maximum committed effective dose equivalent of up to 2.6 mrem (about 2.6 percent of the dose received from natural background radiation.)

7.3 LONG-TERM IMPACTS

No new long-term, unavoidable adverse impacts have been identified for the WIPP project since the 1980 FEIS. The area disturbed during construction and operation of the WIPP would probably always show some slight sign of previous activities despite efforts to return the WIPP site to as close to its original condition as possible. The TRU wastes that would be emplaced underground would not be expected to release any radioactivity or hazardous chemical constituents; therefore, there would be no long-term radiological or chemical impacts (SEIS Subsection 5.2.3, 5.2.4, and 5.4.)

7.4 COMPARISON OF ACTION ALTERNATIVES

The alternative to delay the receipt of TRU waste at the WIPP (Alternative Action) until compliance with the applicable standards has been demonstrated would result in unavoidable adverse impacts similar to those for the Proposed Action. The major difference would be the impacts resulting from conducting the bin-scale tests at a facility other than the WIPP underground facilities. These minor impacts would consist of short-term effects on land use, noise levels, and air quality at the facility selected for the bin-scale tests. The unavoidable adverse impacts of operation of the WIPP after the bin-scale tests would be essentially the same as those for the Proposed Action.

REFERENCES FOR SECTION 7

DOE (U.S. Department of Energy), 1980. Final Environmental Impact Statement, Waste Isolation Pilot Plant, DOE/EIS-0026, Washington DC.

8.0 SHORT-TERM USES AND LONG-TERM PRODUCTIVITY

The impacts of the WIPP project on the short-term uses and long-term productivity of the resources involved would be essentially the same as those described in the FEIS (DOE, 1980).

Use of the WIPP site in southeastern New Mexico for a permanent TRU waste repository could hinder the extraction of mineral and hydrocarbon resources. However, over two-thirds of the total potash reserves previously denied would become available by allowing resource recovery in Control Zone IV of the WIPP site. More than one-half of the hydrocarbon resources within the original WIPP site could be recovered by vertical drilling in Control Zone IV as a result of its unconditional release. The rest of the hydrocarbon resources (i.e., those within the inner zones of the WIPP site) could be reached by directional drilling from Control Zone IV. After decommissioning, the WIPP site would be restored by recontouring, grading, seeding, and other methods to return it to its natural condition.

Conducting bin-scale tests at an existing DOE facility would have a negligible impact on any resources involved. The short-term uses and long-term productivity of the land and associated resources at the selected facility are already controlled and somewhat restricited by the DOE.

REFERENCES FOR SECTION 8

DOE (U.S. Department of Energy), 1980. Final Environmental Impact Statement, Waste Isolation Pilot Plant, DOE/EIS-0026, U.S. Department of Energy, Washington, D.C.

9.0 IRREVERSIBLE AND IRRETRIEVABLE COMMITMENTS OF RESOURCES

The irreversible and irretrievable commitments of resources for the proposed action have not changed substantially from those presented in Section 11 of the FEIS (DOE, 1980). This section identifies the minor changes in these commitments of resources that would result from changes in the proposed action since 1980.

9.1 CONSTRUCTION

The surface facilities and a portion of the underground facilities have been constructed at the WIPP, and the building materials (e.g., concrete and lumber), water, electricity, and fuels (e.g., propane and diesel fuel) required for the construction have been expended. The amounts of these resources that would be required for construction were estimated in Section 11.3 of the FEIS and are probably somewhat greater than the amounts actually used. The cost reduction program of 1982 (SEIS Subsection 7.1) reduced the construction of surface facilities at the WIPP and thereby decreased the consumption of the resources; however, the shortened WIPP construction schedule may have temporarily intensified the demand for the necessary resources.

The alternative to the proposed action would involve construction of a specially designed, aboveground facility for the performance of bin-scale tests at a location other than the WIPP underground facilities. This construction would require the consumption of building materials, water, electricity and fuels. The amounts of these resources that would be required have not been estimated, but these amounts would be very minor in comparison to those used for construction of the WIPP facilities. The effects of these resource requirements on local or regional resource availabilities would depend on the specific site chosen for the aboveground bin-scale tests.

9.2 OPERATION

Operation of the WIPP during both the Test and Disposal Phases would require the consumption of water, electricity, and fuels (e.g., gasoline and diesel fuels). In addition, the transportation of TRU wastes to the WIPP would require the use of diesel fuel for trucks and/or trains. The amounts of these resources that would be required for operation of the WIPP were estimated in Section 11.4 of the FEIS and are not expected to have changed substantially since 1980. However, the amount of diesel fuel required for TRU waste transportation would depend on the locations of the specific DOE facilities that would ship wastes to the WIPP and the transportation modes and routes to be used. It is anticipated that these resource requirements would be substantially less than local or regional availabilities of these resources.

The performance of bin-scale scale tests at an existing DOE facility other than the WIPP underground repository would also require the consumption of water, electricity, and fuels. These resource requirements would be very minor in comparison to those for operation of the WIPP and would have little impact on local or regional resource availabilities depending on the specific location of the facility chosen for the tests.

Throughout operation of the WIPP, the 250 acres of land within the existing Secured Area would not be available for other uses. Upgrading of the WIPP site security facilities would expand the Secured Area and exclude 1,454 acres of land from uses other than those designated by the DOE. After decommissioning of the WIPP, this land would be returned to as close to its original condition as possible and would be available for restricted uses such as grazing. Land uses such as potash mining and oil and gas exploration would always be prohibited within the boundaries of the WIPP site (16 sections or 10,240 acres of land); however, the release of Control Zone IV for unrestricted use would allow recovery of more than two-thirds of the total potash reserves and more than one-half of the total oil and gas resources within the original WIPP site.

The performance of bin-scale tests at an existing DOE facility other than the WIPP underground repository would have a negligible impact on land use and resource recovery. Activities within existing DOE facilities are already controlled or restricted depending on the specific facility chosen for the tests.

REFERENCES FOR SECTION 9

DOE (U.S. Department of Energy), 1980. Final Environmental Impact Statement: Waste Isolation Pilot Plant. DOE/EIS-0026, Washington, D.C.

10.0 ENVIRONMENTAL REGULATORY REQUIREMENTS

This section updates Section 14 of the FEIS regarding the environmental regulatory requirements, such as permits, approvals, and consultations, that are required for the WIPP.

The regulatory changes having the greatest consequences since publication of the FEIS are as follows: 1) the DOE's 1987 interpretive rule regarding by-product materials and 2) the EPA's 1985 environmental radiation protection standards contained in 40 CFR Part 191. The effect of the DOE's 1987 interpretive rule is that DOE-generated radioactive waste which also qualifies as hazardous waste under the Resource Conservation and Recovery Act (RCRA) is subject to dual regulation under RCRA and the Atomic Energy Act (AEA). While a 1987 court decision vacated and remanded Subpart B of 40 CFR Part 191 to the EPA for repromulgation, the DOE has agreed with the State of New Mexico to continue its performance assessment planning as though the 1985 standards remained in effect. Detailed discussions about the implications of these regulatory changes are provided in SEIS Subsections 10.2.1 and 10.2.3.

10.1 PERMITS AND APPROVALS ADDRESSED IN THE FEIS

Tables 10.1 and 10.2 list active permits, approvals and notifications acquired in response to Federal and State requirements. This information was obtained from the Annual Site Environmental Monitoring Report for the Waste Isolation Pilot Plant for calendar year 1987 (DOE, 1988) and was updated with more recent information. Permits obtained that are no longer in effect are listed in the same document. (DOE, 1988).

10.2 ADDITIONAL PERMITS, APPROVALS, AND CONSULTATIONS

Since publication of the FEIS in 1980, it has become necessary to address compliance with several additional regulatory or approval requirements. These are summarized in this subsection.

10.2.1 Resource Conservation and Recovery Act of 1976

When the FEIS was prepared, it was believed that the RCRA, 42 U.S.C. 3251 et seq., did not apply to (mixed waste) radioactive waste contaminated with RCRA-regulated hazardous chemicals. On July 3, 1986 (51 FR 24504), the EPA published a notice of its determination that wastes containing hazardous and radioactive constituents were subject to regulation under RCRA. In the same notice, the EPA notified the states that they must obtain authority from the EPA to regulate the hazardous constituents of "radioactive mixed waste" in order to obtain or retain authorization to administer and enforce a RCRA Subtitle C hazardous waste program.

TABLE 10.1 Active Federal permits, approvals, and notifications

Granting agency	Types of permits, approvals, and notifications	Permit number	Date granted	Date expires
Department of the Interior, Bureau of Land Management	Land use permit to dispose of construction debris	NM-067-LUP-237	02/09/87	02/09/90
Department of the Interior, Bureau of Land Management	Land use permit for placement of raptor platforms	NM-060-LUP-235	09/12/86	09/12/89
Department of the Interior, Bureau of Land Management	Approval to drill two new test wells on existing pads at P-1 and P-2	NA[a]	09/18/86	NA
Department of the Interior, Bureau of Land Management	Right-of-way for water pipeline	NM53809	08/24/83	NA
Department of the Interior, Bureau of Land Management	Right-of-way for north access road	NM55676	08/24/83	NA
Department of the Interior, Bureau of Land Management	Right-of-way for railroad	NM55699	09/27/83	NA
Department of the Interior, Bureau of Land Management	Right-of-way for dosimetry and aerosol sampling sites	NM63136	07/03/86	NA
Department of the Interior, Bureau of Land Management	Right-of-way for seven subsidence monuments	NM65801	11/07/86	NA

TABLE 10.1 Concluded

Granting agency	Types of permits, approvals, and notifications	Permit number	Date granted	Date expires
U.S. Environmental Protection Agency	Notification of two underground fuel storage tanks at the WIPP	NA	04/15/86	NA
U.S. Environmental Protection Agency	Acknowledgment of Notification of Hazardous Waste Activity (TRUPACT)	NM 982283566	10/87	NA
U.S. Environmental Protection Agency	Acknowledgment of Notification of Hazardous Waste Activity (WIPP)	NM 4890139088	01/88	NA
U.S. Environmental Protection Agency	Submission of Part A RCRA Permit Application	NA	07/88 (applied)	NA

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[a] NA = Not applicable

Table 10.2 Active State permits and approvals

Granting agency	Type of permit or approval	Permit number	Date granted	Date expired
New Mexico Environmental Improvement Division	Open burning permit to train fire control crews[a]	NA[b]	02/24/88 (extension)	02/24/89
New Mexico Environmental Improvement Division	Food or purveyor permit for cafeteria	4CA08CARRS184A	10/10/86	NA
New Mexico Department of Game and Fish	Permit to collect biological samples	1775	02/15/89	12/31/89
New Mexico Department of Game and Fish	Concurrence that construction of the WIPP will have no significant adverse impact upon threatened or endangered species	NA	04/07/80	NA
New Mexico Commissioner of Public Lands	Right-of-way for high-volume air sampler	RW-22789	10/03/85	10/03/2020
New Mexico Department of Finance and Administration, Planning Division, Historic Preservation Bureau	Concurrence that the archaeological resources protection plan is adequate to mitigate adverse impacts upon cultural resources resulting from construction of the full WIPP	NA	07/25/83	NA

[a] Permit reapplied for recently

[b] NA = Not applicable

Following the 1986 EPA determination, and after further deliberation, the DOE issued a final "by-product material" interpretive rule on May 1, 1987 (10 CFR Part 962; 52 FR 15937) which determined that DOE-generated radioactive waste which also qualifies as hazardous waste under RCRA is subject to dual regulation under the RCRA and the AEA. The DOE concluded that the term "by-product material" refers only to the radioactive components of nuclear waste streams. This interpretation terminated several years of controversy over the meaning of the RCRA exclusion of "by-product material" in Section 1004(27) of the RCRA. The DOE is committed to full compliance with RCRA requirements.

Although the DOE is committed to compliance by the WIPP with the RCRA requirements pertaining to transportation, waste handling, and waste emplacement of radioactive mixed waste, several RCRA compliance issues remain unresolved as of the time of this SEIS. The three major RCRA compliance issues in need of resolution are briefly summarized below.

<u>Interim Status Authorization</u>. The RCRA provides that owners or operators of facilities "in existence" on the effective date of statutory or regulatory changes (under RCRA) making the facility subject to permitting requirements can qualify for interim status by 1) filing the "preliminary notification" of hazardous waste management activity required by Section 3010(a) and 2) making application for a RCRA permit by submitting Part A of the permit application. The effect of having interim status is that owners or operators are "treated as having been issued such permit until such time as final administrative disposition of such application is made" [Section 3005(e)(1)(C)].

The WIPP qualifies as an "existing facility" for which interim status is available. However, the EPA has taken the position that neither the State nor the EPA can presently confer interim status because 1) the EPA does not have authority to regulate hazardous waste in a state such as New Mexico with an authorized RCRA program and 2) the State does not have either authority under State law or RCRA authorization to regulate radioactive mixed waste at WIPP. Before the State could regulate mixed waste at WIPP under State law or apply to EPA for mixed-waste authorization, it was first necessary for the State legislature to amend Section 74-4-3.2 of the New Mexico Hazardous Waste Act by deleting that Section's specific exemption for the WIPP. That amendment was enacted by the State legislature during its 1989 session.

The DOE has taken every possible step to qualify the WIPP as an interim status facility by 1) submitting a preliminary notification and Part A of the RCRA permit application to the New Mexico Environmental Improvement Division (EID) and to the EPA Region VI and 2) taking necessary steps to ensure that the WIPP complies with the interim status regulatory requirements of 40 CFR Part 265.

Now that the State legislature has amended the New Mexico Hazardous Waste Act, the State currently has authority to regulate mixed waste at WIPP under State law. In addition, it is expected that New Mexico will submit an application to the EPA for the requisite RCRA authority over radioactive mixed waste on or before July 1, 1989.

Waste Characterization. The RCRA regulations in 40 CFR Part 265.13 require that anyone who treats, stores, or disposes of hazardous waste must obtain a "detailed chemical and physical analysis of a representative sample of the waste." The land disposal restriction requirements, discussed below, also require, in 40 CFR Part 268.7, a waste analysis, or use of knowledge of the waste, to determine if waste to be land disposed meets the treatment standards. Complete waste characterization data for waste expected to be shipped to the WIPP is not yet available. Waste characterization data exists for waste currently generated. However, waste characterization for TRU waste that has been in storage for a number of years ("old" waste) has relied solely on knowledge of the process from which the waste was derived as provided for in 40 CFR Part 262.11(c)(2). Although it may be less detailed, the characterization of old waste through knowledge of process is preferred by the DOE because opening great numbers of stored containers to collect and analyze "representative samples" of TRU waste would pose a radiological risk to workers. In addition, the sampling of old waste for characterization purposes also would generate substantial amounts of additional waste for each barrel sampled. Before any TRU waste is transported to the WIPP, the extent to which further waste characterization is required will be resolved with the EPA and/or the State of New Mexico.

Land Disposal Restrictions. The 1984 Hazardous and Solid Waste Amendments (HSWA) required that levels or methods of treatment be established for groups of chemical and toxic wastes that would diminish a waste's toxicity or reduce the likelihood that a waste's hazardous constituents would migrate. Furthermore, these amendments prohibited the land disposal of wastes not meeting the treatment standards according to a schedule of statutory deadlines ending May 8, 1990. Some TRU mixed waste contains these chemical and toxic elements subject to the land disposal restrictions. Thus, some portion of the TRU mixed waste intended for emplacement at the WIPP will be subject to the land disposal restrictions. Several options are available under the regulations for accommodating these restrictions.

The DOE is currently pursuing a "no migration" variance from the land disposal restrictions. The DOE has submitted a "no migration" variance petition to EPA headquarters. EPA regulations provide that the EPA will consider allowing the disposal of untreated restricted hazardous waste if a petitioner can demonstrate to the EPA "to a reasonable degree of certainty, that there will be no migration of hazardous constituents from the disposal unit. . .for as long as the wastes remain hazardous." "No migration" variance petitions to allow the land-disposal of prohibited wastes are governed by 40 CFR Part 268.6. Granting such a variance would mean that the defense program facilities could ship to and have emplaced in the WIPP, radioactive mixed waste that would otherwise be prohibited from land disposal. If the no-migration variance is not granted, the DOE will consider other ways to comply with the EPA regulations. These might include treating wastes in accordance with existing land-disposal restriction standards or proposing alternative approaches in accordance with established EPA procedures. The DOE may also examine the desirability of performing tests with TRU wastes not covered by land-disposal restriction standards.

10.2.2 Clean Air Act

The EPA is charged with regulating hazardous air pollutants, under Section 112 of the Clean Air Act, 42 U.S.C. 7412(b)(1)(B). In 1983, the EPA published proposed National Emissions Standards for Hazardous Air Pollutants (NESHAPs) regulating radionuclide emissions from four source categories. DOE facilities constituted one of those four source categories. In 1985, the EPA promulgated final radionuclide NESHAPs for DOE facilities. The 1985 NESHAPs are set forth at Subpart H of 40 CFR Part 61.

The DOE is currently preparing a NESHAPs notice of anticipated date of facility start-up that will be filed with EPA in accordance with 40 CFR 61.09.

10.2.3 Federal Land Policy and Management Act

The 10,240 acres occupied by the WIPP site are now public lands under the jurisdiction of the BLM. The DOE conducted the Site and Preliminary Design Validation (SPDV) phase of the WIPP project and proceeded with full construction under two successive administrative land withdrawals: Public Land Order 6232, effective March 30, 1982; and Public Land Order 6403, effective June 29, 1983. These land withdrawals were necessary to protect the geologic integrity of the site while proceeding with site validation investigations and construction. However, the withdrawals do not permit receipt and storage of TRU or TRU mixed waste.

In order to allow the WIPP to receive radioactive waste for experimentation and operational demonstration purposes, bills were introduced in the first session of the 100th Congress in the House of Representatives and the Senate. The proposed legislation, cited as the "WIPP Land Withdrawal Act of 1987," would have resulted in a permanent transfer of the WIPP site lands from the Department of the Interior (DOI) to the DOE. The Congress adjourned before a bill could be enacted.

Legislative withdrawal is again being pursued in the 101st Congress and is supported by the DOE as the preferred mechanism for withdrawal of the WIPP site lands. However, the DOE has also filed an application with BLM requesting an administrative withdrawal of the WIPP site acreage. The DOE is seeking administrative withdrawal as a course of action parallel to the preferred legislative withdrawal. The BLM is participating as a cooperating agency on this SEIS.

Administrative land withdrawals by the Secretary of the Interior are authorized and limited by Section 204 of the Federal Land Policy and Management Act (FLPMA) of 1976 (43 U.S.C. Section 1714). "Withdrawal" is defined in Section 103(j) of the FLPMA as withholding of Federal land in order to (among other things) limit activities on the land, reserve the area for a particular public purpose or program, or transfer jurisdiction from one agency to another.

While a legislative withdrawal of the WIPP land would be a permanent withdrawal, the FLPMA authorizes the Secretary of the Interior to withdraw 5,000 acres or more for an initial period not to exceed 20 years. The Secretary of the Interior must notify the House of Representatives and the Senate of the withdrawal no later than the date it is to become effective. Under FLPMA, the Congress may terminate the withdrawal by adopting a concurrent resolution disapproving the withdrawal.

Within 90 days of notifying the Congress of an administrative withdrawal of the type required for the WIPP, the DOI must submit a number of information items to the appropriate Congressional committees including, but not limited to:

- A clear explanation of the proposed use of the land
- An inventory of current natural resources, uses, and values of the land to be withdrawn as well as adjacent land uses and values
- An analysis of any conflicting or incompatible uses
- A discussion of consultations made or to be made with other Federal agencies, State and local government, and other "appropriate" individuals and groups
- The time and place of hearings and other opportunity for public involvement
- A detailed report on mineral values.

The FLPMA in Section 204(h) requires that "all new withdrawals made by the Secretary under this section . . . shall be promulgated after an opportunity for a public hearing." If it becomes necessary to complete the processing of the administrative land withdrawal for which application has been made, the DOE will cooperate fully with the DOI in complying with all of the procedural and administrative requirements of FLPMA. Opportunities for public hearings and other public involvement are required under 43 CFR 2310. Public comments obtained during public hearings on this SEIS, as well as all other public (including written) comments submitted to the DOE on the SEIS, will be provided to the BLM in its role as a cooperating agency on the SEIS.

10.2.4 Environmental Radiation Protection Standards for Management and Disposal of Spent Nuclear Fuel, High-Level, and Transuranic Radioactive Wastes (40 CFR Part 191)

The authority of the EPA to establish radiation protection standards that apply to disposal activities and defense activities under the jurisdiction of the DOE derives from the AEA of 1954 (42 U.S.C. 7101 et seq.), Reorganization Plan Number 3 of 1970. Pursuant to this authority, the EPA in 1985 issued final radiation protection standards that are set forth in 40 CFR Part 191.

The EPA standards apply to spent nuclear fuel, high-level radioactive wastes as defined by the Nuclear Waste Policy Act (NWPA), and TRU wastes containing more than 100 nCi/g of alpha-emitting TRU isotopes. They are divided into two subparts, described below.

Subpart A, "Standards for Management and Storage," sets limits on annual doses to members of the public from management and storage operations at any disposal facility that is operated by DOE and not regulated by the NRC. The standards provide that the management and storage of wastes at such facilities shall be conducted in such a manner as to provide reasonable assurance that the combined annual dose equivalent to any member of the public in the general environment from such operations shall not exceed 25 mrem to the whole body and 75 mrem to any critical organ. Subpart A also allows the EPA to set alternative standards applicable to DOE facilities. Because the WIPP will not be a disposal facility during the Test Phase, Subpart A technically does not apply to the Test Phase. However, as discussed below, the DOE has agreed with the State of New Mexico that the DOE will comply with the standards of Subpart A upon the initial receipt of wastes at the WIPP and thereafter. The final safety analysis report, which will be issued by the DOE prior to the receipt of waste, will document the DOE's ability to comply with the provision of Subpart A of 40 CFR 191.

Subpart B, "Standards for Disposal," establishes several sets of requirements:

- Containment Requirements: limit projected releases of radioactivity to the "accessible environment" for 10,000 years after disposal

- Assurance Requirements: (six in all) selected to provide confidence that containment requirements can be met

- Individual Protection Requirements: limit annual exposures to members of the public in the accessible environment to 25 mrem to the whole body or 75 mrem to any organ for 1,000 years after disposal

- Groundwater Protection Requirements: limit radioactive concentrations in Class I groundwaters for 1,000 years after disposal

- Guidance for Implementation: indicates how the EPA provides guidance or compliance with the various numerical standards.

The assurance requirements (40 CFR Part 191.14) mandate, among other things, active institutional controls (e.g., boundary markers, land records entries, etc.) over disposal sites for as long a period of time as is "practicable" after disposal. However, for the purposes of assessing the performance of a geologic repository, these institutional controls are assumed not to contribute to waste isolation longer than 100 years following disposal.

The containment requirements of 40 CFR Part 191.13 require that radioactive waste disposal systems be designed to provide a "reasonable expectation" that cumulative releases of radionuclides over 10,000 years will not exceed the levels specified in Appendix A, Table 1. It is not anticipated by the standards that containment requirements will be met with absolute assurance, since "there will inevitably be substantial uncertainties in projecting disposal system performance" [40 CFR Part 191.13(b)].

Performance assessments designed to provide a reasonable expectation that the WIPP will comply with the 40 CFR Part 191 geologic repository containment and individual protection requirements are part of the Test Phase discussed in SEIS Subsection

3.1.1.4. If the performance assessments indicate that the WIPP does not have a reasonable expectation of complying with the Subpart B requirements, the DOE will consider a number of options, as discussed in Subsection 2.5.

In response to a challenge by the Natural Resources Defense Council (NRDC), the U.S. Court of Appeals for the First Circuit vacated and remanded to the EPA Subpart B of 40 CFR Part 191 for reconsideration and repromulgation. Thus, legally, that portion of the radiation environmental protection standards are not now in effect.

Following the court's decision in NRDC v. EPA, the DOE and the State of New Mexico (August 4, 1987) entered into an agreement, referred to as the Second Modification to the "Agreement for Consultation and Cooperation" (C&C Agreement), which provides that the DOE would:

- Comply with the standards of 40 CFR Part 191, Subpart A upon the initial receipt of waste at WIPP
- Provide the State by February 1, 1988, with a plan describing the steps DOE will undertake to demonstrate compliance with the assurance requirements of 40 CFR Part 191.14
- Prior to receiving more than 15 percent, by volume of the WIPP's TRU waste capacity, demonstrate that the WIPP meets the applicable environmental standards for the disposal of radioactive waste established in Subpart B of the EPA standards, including the assurance requirements under such Subpart B, in effect at that time.

In recognition of the fact that Subpart B of 40 CFR Part 191 had been vacated and remanded for reissuance, the Second Modification provided as follows:

> While the standards are on remand to the EPA for reconsideration pursuant to the July 17, 1987 opinion . . . DOE agrees to continue its performance assessment planning as though the provisions of 40 CFR 191 effective November 19, 1985 remain applicable.

The DOE will continue to guide its performance-assessment efforts as though the various assurance requirements and environmental protection standards of the vacated regulations are still in effect.

10.2.5 Consultations with the State of New Mexico

The Department of Energy National Security and Military Applications of Nuclear Energy Authorization Act of 1980 (PL 96-164), which authorized the WIPP project (SEIS Subsection 1.1), provides as follows in Section 213(b):

> 1) In carrying out such project, the Secretary shall consult and cooperate with the appropriate officials of the State of New Mexico, with respect to the public health and safety concerns of such state in regard to such project and shall, consistent with the purposes of subsection a, give consideration to

such concerns and cooperate with such officials in resolving such concerns. The consultation and cooperation required by this paragraph shall be carried out as provided in Paragraph 2.

2) The Secretary shall seek to enter into a written agreement with the appropriate officials of the State of New Mexico, as provided by the laws of the State of New Mexico, not later than September 30, 1980, setting forth the procedures under which the <u>consultation and cooperation</u> required by paragraph 1 shall be carried out. Such procedures shall include as a minimum:

a) the right of the State of New Mexico to comment on, and make recommendations with regard to, the public health and safety aspects of such project before the occurrence of certain key events identified in the agreement

b) procedures, including specific time frames, for the Secretary to receive, consider, resolve, and act upon comments and recommendations made by the State of New Mexico

c) procedures for the Secretary and the appropriate officials of the State of New Mexico to periodically review, amend, or modify the agreement.

In 1981, the State of New Mexico brought suit in the United States District Court for the District of New Mexico (<u>State of New Mexico v. U.S. Department of Energy</u>, Civil Action No. 81-0363 JB) to address four State concerns:

1) That no decision on WIPP construction be made until the DOE shared with the State the results of the Site and Preliminary Design Validation Program (SPDV)

2) That the State be assigned "final resolution" of all off-site State health and safety concerns prior to WIPP construction

3) That the State and the DOE enter into a "binding and enforceable consultation and cooperation agreement"

4) That the FLPMA be complied with for any withdrawal of lands from the public domain for the WIPP.

Subsequently, the District Court ordered a "stay" (postponement) of the suit in recognition of the fact that the State and the DOE had entered into a "Stipulated Agreement Resolving Certain State Off-site Concerns Over WIPP."

The Stipulated Agreement has 14 provisions, the principal one being that the DOE and the State of New Mexico execute a "consultation and cooperation agreement" in order to provide "timely exchange of information" about the WIPP. The agreement also provides for conflict resolution on matters "relating to the public health, safety or welfare of the citizens of the State."

The C&C Agreement was appended to the Stipulated Agreement as Appendix A. The C&C Agreement has 11 major articles. Among other things, it provides for the DOE to give prior written notice to the State before the occurrence of 17 "key events" or "milestones" during the life of the project, up to and including decontamination and decommissioning.

The Stipulated Agreement was supplemented on December 27, 1982. This Supplemental Stipulated Agreement, the filing of which completed the lawsuit settlement process, addressed five major areas:

- State liability
- Emergency response preparedness
- Transportation monitoring of WIPP waste
- WIPP environmental operations monitoring by the State of New Mexico
- Upgrading of State highways.

These agreements between the State and the DOE are available to the public and have been placed in numerous libraries and reading rooms around the State (see Appendix K). The C&C Agreement and a "working agreement" for the C&C Agreement have been modified several times by mutual agreement as follows:

- Working Agreement for Consultation and Cooperation Agreement, Revision 1 - March 22, 1983
- First Modification to the Agreement for Consultation and Cooperation--November 27, 1984. This modification addressed six issues: 1) specific mission of the WIPP, 2) demonstrating retrievability of WIPP waste, 3) post-closure control, 4) completion of additional testing, 5) compliance with applicable Federal regulatory standards, and 6) encouraging the hiring of New Mexico residents at the WIPP site.
- Second Modification to the Agreement for Consultation and Cooperation--August 4, 1987. This modification addressed surface and subsurface mining, salt disposal, and compliance with EPA, DOT, and NRC regulations.
- Modification to the Working Agreement of the Consultation and Cooperation Agreement--March 22, 1988. This modification addresses on-going field investigations, monitoring and testing, and establishes "target dates."

The institutional bodies specifically charged with implementing these various agreements and modifications for the State are the New Mexico Radioactive Waste Consultation Task Force and the Environmental Evaluation Group. In addition, the DOE interfaces regularly with the New Mexico Environmental Improvement Division and with the New Mexico Legislature's Radioactive and Hazardous Waste Committee, as those bodies carry out oversight activities on behalf of the state.

10.2.6 Nuclear Regulatory Commission (NRC) TRUPACT-II Certification

The Second Modification of August 4, 1987 to the C&C Agreement between DOE and the State of New Mexico, discussed in SEIS Section 10.2.5, contains the following provision:

> The transportation of radioactive waste to WIPP shall comply with the applicable regulations of the U.S. Department of Transportation and any applicable corresponding regulations of the U.S. Nuclear Regulatory Commission. All waste shipped to WIPP will be shipped in packages which the Nuclear Regulatory Commission has certified for use.

The applicable DOT regulations are contained in 49 CFR Part 173: "Shippers--General Requirements for Shipments and Packagings." Packaging requirements for radioactive materials, including requirements for Type B packages proposed for shipments of TRU waste to the WIPP, are detailed in 49 CFR Part 173, Subpart I.

The NRC requirements for "Packaging and Transportation of Radioactive Materials" are contained in 10 CFR Part 71, which references the DOT regulations. Package approval standards are set forth in 10 CFR Part 71, Subpart E, and the general standards for all packages are presented in detail in 10 CFR 71.43.

The transportation parameters that will be regulated for ensuring safe shipment of the package are listed below, along with a brief description of each parameter.

1) Waste Physical Form. The physical form of the waste is restricted to solid or solidified material. Liquid waste is prohibited except for residual amounts that are less than 1 percent by volume. Sharp objects that might affect the integrity of the waste containers are prohibited from the waste, unless they are adequately padded to prevent damage to the containers.

2) Chemical Form and Chemical Properties. Four types of chemical constituents are prohibited from the TRUPACT-II payload. These are a) compressed gases, b) explosive materials, c) nonradionuclide pyrophoric materials, and d) corrosive materials. These restrictions on the chemical constituents of the waste are needed in order to limit the amount of potentially flammable gases (hydrogen, for example) that might be generated from the waste by radiolysis.

3) Chemical Compatibility. Chemical compatibility means that no adverse chemical processes can occur during shipment that might pose a threat to safe shipping of the payload in the TRUPACT-II package. Specifically, this parameter is used to evaluate the following four conditions:

   a) Chemical compatibility of the waste form within each individual waste container.

   b) Chemical compatibility between waste containers during the hypothetical accident condition. In the hypothetical accident, no credit is taken for the structural integrity of the individual waste containers during the accident conditions. All of the waste containers are assumed to breach, and the contents from all the individual waste containers are assumed to mix together. Not only must the contents within a secondary container (drum or standard waste box) be compatible, the contents between different containers within the TRUPACT-II container must also be compatible. The integrity of the Type B TRUPACT-II package can be assumed for hypothetical accident conditions.

   c) Chemical compatibility of the waste forms with the TRUPACT-II Inner Containment Vessel (ICV).

   d) Chemical compatibility of the waste forms with the TRUPACT-II o-ring seals.

4) Gas Distribution and Pressure Buildup. The acceptable design pressure in the TRUPACT-II cavity is 50 lb per square inch gauge (psig). The payload is limited so that this design pressure is never exceeded. In addition, the gas generation from the payload (which could occur primarily due to radiolysis) is controlled to prevent the occurrence of potentially flammable concentrations of gases in the payload or the package. This is done by limiting the decay heat (radionuclide concentration) within the waste containers and by limiting the chemical constituents of the waste (gas generation can result from the waste constituents being irradiated by the radionuclides).

5) Waste Packaging and Waste Containers. Two types of waste containers are permitted for shipment in TRUPACT-II: 55-gal drums or standard waste boxes (SWBs). These must meet DOT Type 7A specifications. A payload shipment consists of either 14 drums or two SWBs. Restrictions apply to the components of these secondary waste containers and can be subdivided as follows:

   - If the waste is packaged in plastic bags, the number of these in each secondary container must be known. Bags must be closed only by a twist and tape method at the end.

   - If a rigid drum liner (usually a 90-mil high-density polyethylene liner) is present in a secondary container, it must either be punctured or vented with a carbon composite filter.

   - Secondary containers must be vented with HEPA grade carbon composite filters, which allow the passage of gaseous products while retaining particulates.

6) Decay Heat and Fissile Materials. Decay heat limits are imposed on each secondary container, as well as on the total TRUPACT-II payload, to keep potential gas generation below safe limits. In addition, the fissile material in the secondary containers and the total payload is restricted so as to remain below criticality limits even under hypothetical accident conditions.

7) Weight. Weight limits apply to individual secondary containers and to the total payload and are as follows:

   - 1000 lb/drum
   - 4000 lb/SWB
   - 7000 lb/TRUPACT-II payload

8) Radiation Dose Rates. The radiation dose rate parameter evaluates the external dose rates of individual waste containers and of the loaded TRUPACT-II which should meet the requirements of safe shipping and handling.

REFERENCES FOR SECTION 10

DOE (U.S. Department of Energy), 1988. Annual Site Environmental Monitoring Report for the Waste Isolation Pilot Plant, CY 1987, DOE/WIPP-88-009, Carlsbad, New Mexico.

GLOSSARY

absorbed dose	The energy imparted to matter by ionizing radiation per unit mass of irradiated material at the place of interest. The unit of absorbed dose is the rad. (See rad.)
actinide	An element in the series beginning with element 90 and continuing through element 103. All the transuranic nuclides considered in this document are actinides.
activity	The number of nuclear transformations occurring in a given quantity of material per unit time (See curie, radioactivity.)
AIRDOS-EPA	A computer code endorsed by the Environmental Protection Agency for predicting radiological doses to members of the public due to airborne releases of radioactive material. Includes inhalation, external exposure to direct radiation, and food ingestion pathways.
alpha particle	A charged particle emitted from the nucleus of an atom having a mass and charge equal in magnitude of a helium nucleus; i.e., two protons and two neutrons.
anhydrite	A mineral consisting of anhydrous calcium sulfate: $CaSO_4$. It is gypsum without its water of hydration and is denser, harder, and less soluble than gypsum.
anticline	A fold of rocks whose core contains the stratigraphically older rocks; it is convex upward.
aquiclude	The saturated but poorly permeable underground formation that impedes groundwater movement and does not yield water freely to a well or spring.
aquifer	A body of rock that contains enough saturated permeable material to transmit groundwater and to yield significant quantities of groundwater to wells and springs. The opposite of an aquiclude.
argillaceous rocks	Rocks containing appreciable amounts of clay.
atom	Smallest unit of an element which is capable of entering into a chemical reaction.

average life	The average of the individual lives of all the atoms of a particular radioactive substance. It is 1.443 times the radioactive half-life.
backfill	Salt, or a mixture of salt and other materials, used to reduce void volumes in storage panels and drifts.
background radiation	Radiation arising from radioactive material other than the one directly under consideration. Background radiation due to cosmic rays and natural radioactivity is always present. There may also be background radiation due to the presence of radioactive substances in other parts of the building, in the building material itself, etc.
basin	An extensive depressed area into which the adjacent land drains, and having no surface outlet.
bedded salt	Consolidated layered salt separated from other layers by distinguishable planes of separation.
Bell Canyon Formation	A sequence of rock strata that forms the topmost unit of the Delaware Mountain Group.
berm	A narrow ledge or shelf, as along a slope.
beta particle	Charged particle emitted from the nucleus of an atom, with a mass and charge equal in magnitude to that of the electron.
bin-scale tests	Sealed bins where TRU wastes and other materials are stored in order to determine chemical and physical interactions.
breccia	A clastic sedimentary rock composed of angular rock fragments greater than 2 mm in diameter.
caliche caprock	A desert soil formed by the near-surface crystallization of calcite and/or other soluble minerals by upward-moving solutions.
canister	As used in this document, a container, usually cylindrical, for remotely-handled waste, spent fuel, or high-level waste. The waste will remain in this canister during and after burial. A canister affords physical containment but not shielding; shielding is provided during shipment by a shipping cask.
carcinogen	A substance which causes or induces cancer.

cask	A massive shipping container providing shielding for highly radioactive materials and holding one canister.
Castile Formation	A formation of evaporite rocks (interbedded halite and anhydrite) of Permian age that immediately underlies the Salado Formation.
clastic	Referring to a rock or sediment composed primarily of broken fragments of pre-existing rocks or organisms.
cloudshine	The exposure from cloudshine is the direct external dose from the passing cloud of dispersed material.
committed dose equivalent	The dose equivalent to organs or other tissues that will be received following an intake of radioactive material during the 50-year period following that intake.
committed effective dose equivalent	The weighted sum of committed dose equivalents to dose organs, using weighting factors based on the susceptibility of each organ to certain health effects.
conservative	When used with predictions or estimates, leaning on the side of pessimism. A conservative estimate is one in which the uncertain inputs are used in the way that maximizes the impact.
contact-handled waste	Waste that does not require shielding other than that provided by its container in order to protect those handling it.
contamination	Deposition of radioactive material in any place where it is not desired, particularly where its presence may be harmful.
control zone	At the WIPP, one of several areas of land whose use is governed by controls and restrictions.
creep	1) The slow, imperceptible motion of rock material downslope by gravitational forces. 2) The continuous, usually slow deformation of rock resulting from constant stress acting over a long period of time.
creep closure	Closure of underground openings, especially openings in salt, by plastic flow of the surrounding rock under lithostatic pressure.
criticality	The state of a mass of fissionable material when it is sustaining a chain reaction.

Culebra Dolomite	The lower of two layers of dolomite within the Rustler Formation that are locally water bearing.
curie	The special unit of activity. One curie equals 3.700 X 10^{10} nuclear transformations per second. Abbreviated Ci. Several fractions of the curie are in common usage. microcurie: One-millionth of a curie (3.7 X 10^{4} disintegrations per second). Abbreviated μCi. millicurie: One-thousandth of a curie (3.7 x 10^{7} disintegrations per second). Abbreviated mCi. picocurie: One-millionth of a microcurie (3.7 x 10^{-2} disintegrations per second or 2.22 disintegrations per minute). Abbreviated pCi; replaces the term $\mu\mu$c.
darcy	A unit of permeability equal to 10^{-12} m^2.
Darcy's Law	A means of describing flow through porous media.
daughter	Synonym for decay product.
decay (radioactive)	Process in which a nucleus emits radiation and undergoes spontaneous transformation into one or more different nuclei.
decontamination	The removal of unwanted material (especially radioactive material) from the surface or from within another material.
decommissioning	The process of removing a facility from operation. It is then mothballed, entombed, decontaminated, and dismantled or converted to another use.
defense program waste	Nuclear waste deriving from the manufacture of nuclear weapons and the operation of naval reactors. Associated activities such as the research in the weapons laboratories also produce defense waste.
Delaware Basin	An area in southeastern New Mexico and adjacent parts of Texas where a sea deposited large thicknesses of evaporites some 200 million years ago. It is partially surrounded by the Capitan Reef.
diffusion, atmospheric	Movement of a contaminant due to the cumulative effect of the random motions of the air. Equivalent to eddy diffusion.

Disposal Phase	The approximately 20-year period by which DOE proposes to permanently emplace TRU wastes in the WIPP.
dolomite	A sedimentary rock consisting primarily of the mineral dolomite ($CaMg(CO_3)_2$). It is commonly found in limestone.
dome	A roughly symmetrical upfold, the beds dipping in all directions, more or less equally from a point.
dose	A general form denoting the quantity of radiation or energy absorbed. For special purposes it must be appropriately qualified. If unqualified, it refers to absorbed dose. (The unit of absorbed dose is the rad.)
dose equivalent	A quantity used in radiation protection for expressing the effects of all radiations on a common scale with respect to the relative biological effect. It is defined as the product of the absorbed dose in rads and certain modifying factors. (The unit of dose equivalent is the rem.)
drift	A horizontal mine passageway.
dual porosity	Having fracture porosity as well as interconnected pores.
dyne	The unit of force which, when acting upon a mass of one gram, will produce an acceleration of one centimeter per second per second.
eolian	Applied to deposits arranged by the wind, as the sands and other loose materials along shores, etc.
erpeirogenic movement	The broad movements of uplift and subsidence which affect the whole or large portions of continental areas.
erg	Unit of work done by a force of one dyne acting through a distance of one cm. Unit of energy which can exert a force of one dyne through a distance of one cm; cgs units: dyne-cm or $gm\text{-}cm^2/sec^2$.
evaporites	Sedimentary rocks composed primarily of minerals produced from a saline solution that became concentrated by evaporation of the solvent such as rock salt, sylvite, langbeinite, and anhydrite.

exposure	A measure of the ionization produced in air by x or gamma radiation. It is the sum of the electrical charges on all ions of one sign produced in air when all electrons liberated by photons in a volume element of air are completely stopped in air, divided by the mass of the air in the volume element. The special unit of exposure is the roentgen.
fault	A fracture or fracture zone along which there has been displacement of the sides relative to one another. normal fault: A fault at which the hanging wall has been depressed, relative to the footwall. thrust fault: A reverse fault that is characterized by a low angle of inclination with reference to a horizontal plate.
Federal Land Policy and Management Act (FLPMA)	This 1976 Act governs DOI activities, including administrative withdrawal of BLM public lands. (Section 204)
Final Safety Analysis	This document, prepared in compliance with DOE Order 5481.1B, is the completed formal evaluation of WIPP facilities and operations to systematically identify the hazards of operations, to describe and analyze the adequacy of the measures taken to eliminate, control, or mitigate identified hazards, and to analyze and evaluate potential accidents and their associated risks. (Currently being finalized.)
Final Environmental Statement Impact (FEIS)	This document was prepared by DOE in 1980 in accordance with the National Environmental Policy Act of 1969. This report identifies and analyzes in detail the environmental impacts of the proposed action to place defense-generated transuranic wastes at the WIPP and the feasible alternatives.
fissile	Of a nuclide, capable of undergoing fission by interaction with slow neutrons.
fission (nuclear)	A nuclear transformation characterized by the splitting of a nucleus into a least two other nuclei and the release of a relatively large amount of energy.
fluvial	Of, or pertaining to, rivers; produced by river action.
forb	A non-woody plant that is not grass or grass-like.

40 CFR Part 191	EPA standard for managing and disposing of spent nuclear fuel, high-level, and transuranic wastes. Subpart A deals with managing and storage of wastes while Subpart B covers long-term isolation and disposal.
fugitive dust	Soil particles entrained in air due to construction equipment, vehicles, or wind erosion.
gamma ray	Short wavelength electromagnetic radiation emitted from the nucleus with typical energies ranging from 10 keV to 9 MeV.
gas getter	Materials which have an ability to remove gases from the atmosphere by chemical means.
geosyncline	Large generally linear trough that subsided deeply throughout a long period of time in which a thick succession of stratified sediments and possibly extrusive volcanic rocks commonly accumulated.
glove box	A sealed box in which workers, remaining outside and using gloves attached to and passing through openings in the box, can safely handle and work with radioactive materials.
groundshine	The exposure from groundshine is the direct external dose from material that has deposited on the ground after being dispersed from an accident site.
groundwater	All subsurface water, especially that which comprises the zone of saturation beneath the water table.
grout plugs	Barrier in boreholes or excavated areas consisting of grout material designed to impede liquid movement.
half-life	Time required for a radioactive substance to lose 50 percent of its activity by decay. Half-life is a unit of measure used to project the length of time that these materials remain radioactive. Each radionuclide has a unique half-life; that is, half of a particular nuclide will decay in a specified amount of time; then half of the remaining portion will decay in the same amount of time, and so on, until the material is spent.
halite	The mineral rock salt: NaCl.
hazard index	The hazard index (HI) for a given chemical may be defined as the ratio between the daily intake of that chemical and an acceptable reference level.

hazardous waste	Nonradioactive chemical toxins or otherwise dangerous materials such as sodium, heavy metals, beryllium, and some organics.
head	When used alone, it is understood to mean static head. The static head is the height above a standard datum of the surface of a column of water (or other liquid) that can be supported by the static pressure at a given point.
head-space gases	The gases in the head space of a container that are generated from biological, chemical, and radiolytic processes occurring in the waste. The head space of a container is the space between the container lid and the waste inside the container.
HEPA filter	(High Efficiency Particulate Air.) Material that captures entrained particles from an air stream, usually with efficiencies in the 99.95% and above range for particle sizes of 0.3 micron. Filter material is usually a paper or fiber sheet that is pleated to increase surface area.
high-level waste	Radioactive waste resulting from the reprocessing of spent nuclear fuel. Discarded, unreprocessed spent fuel is also high-level waste. It is characterized by intense, penetrating radiation and by high heat-generation rates. Even in protective canisters, high-level waste must be handled remotely.
horizon	In this document, an underground level. The waste-emplacement horizon in the WIPP is the level about 2,150 feet deep at which openings would be mined for waste disposal.
hot cell	A heavily shielded enclosure for handling and processing (by remote means or automatically) or storing highly radioactive materials.
hydraulic conductivity	A quantity defined in the study of groundwater hydraulics that describes the rate at which water flows through an aquifer. It is measured in feet per day or equivalent units. It is equal to the hydraulic transmissivity divided by the thickness of the aquifer.
hydraulic transmissivity	A quantity defined in the study of groundwater hydraulics that describes the rate at which water may be transmitted through an aquifer. It is measured in ft^2/day or equivalent units.
igneous	A rock or mineral that formed from molten material.

in situ	In the natural or original position. The phrase is used in this document to distinguish in-place experiments, rock properties, and so on, from those in the lab.
isotopes	Atoms having the same number of protons in their nuclei, but differing in the number of neutrons. Almost identical chemical properties exist between isotopes of a particular element.
karst	An erosional topography characterized by sinkholes, caves, and disappearing streams formed by groundwater in limestone, dolomite, and evaporite bedrock.
langbeinite	A mineral used by the fertilizer industry as a source of potassium sulfate.
Linear Energy Transfer	The rate at which energy is deposited in a medium as radiation passes through the medium. For example, alpha particles are low penetrating and high LET radiation because they give up their energy quickly to matter while X-rays are high penetrating and low LET radiation.
lithic	Pertaining to or consisting of stone.
lithostatic pressure	The vertical pressure at a point in the Earth's crust, equal to the pressure exerted by the weight of the overlying rock and/or soil.
Los Medanos	The geographic name for the area surrounding the WIPP site in southeastern New Mexico. In Spanish it means "dune country."
man-rem	A unit of population dose; used interchangeably with person-rem.
material-at-risk	The fraction of each radionuclide or hazardous chemical component of the total inventory available for release in a given scenario.
maximally exposed individual	A hypothetical person who is exposed to a release of radioactivity in such a way that he receives the maximum possible individual dose or dose commitments. For instance, if the release is a puff of contaminated air, the maximally exposed person is at the point of largest ground-level concentration, and remains there during the total time of cloud passage. The use of this term is not meant to imply that there really is such a person, but only that thought is being given to the maximum exposure a person could receive.

metamorphism	Process by which consolidated rocks are altered in composition, texture, or internal structure by conditions and forces not resulting simply from burial and the weight of subsequently accumulated overburden.
micro	A prefix meaning one millionth (1/1,000,000 or 10^{-6}).
milli	A prefix meaning one thousandth (1/1,000 or 10^{-3}).
nano	A prefix meaning one billionth (1/1,000,000,000 or 10^{-9}).
Nash Draw	A shallow 5-mile-wide valley open to the southwest, located to the west of the WIPP facility.
National Environmental Policy Act (NEPA)	This 1969 Act was designed to promote inclusion of environmental concerns in Federal decision-making.
nuclide	A species of atom characterized by the number of protons (Z), number of neutrons (N), and energy state.
overpack	A container put around another container. In the WIPP, overpacks would be used on damaged or otherwise contaminated drums, boxes, and canisters that it would not be practical to decontaminate.
particulates	Fine liquid or solid particles such as dust, smoke, or fumes found in the air or emissions.
peneplain	A nearly flat land surface representing an advanced stage of erosion.
permeability	A property of a mass of soil or rock defined in the study of groundwater hydraulics as the rate at which water can flow through that mass. It is measured in feet per day or equivalent units. It is equal to the hydraulic transmissivity divided by the thickness of the aquifer.
person-rem	A unit of population dose; used interchangeably with man-rem.
pico	A prefix meaning one trillionth (1/1,000,000,000,000 or 10^{-12}).
plutonium equivalent curie (PE-Ci)	A radioactive hazard index factor which relates the radiotoxicity of TRU radionuclides to that of plutonium-239 (see SEIS Appendix F).
pluvial	Due to the action of rain.

polyhalite	An evaporite mineral: $K_2MgCa_2(SO_4)_4 \cdot 2H_2O$. It is a hard, poorly soluble mineral with no economic value.
porosity	The porosity of a rock or soil is its property of containing interstices or voids and may be expressed quantitatively as the ratio of the volume of its interstices to its total volume.
potash	A potassium compound, especially as used in agriculture or industry.
potentiometric surface	The surface of the hydraulic potentials of an aquifer. It is usually represented in figures as a contour map, each point in which tells how high the water would rise in a well tapping that aquifer at that point.
preoperational appraisal	An appraisal of a facility whose purpose is to determine whether procedures and hardware are sufficient to allow the facility to become operational. The term "operational readiness review" is sometimes used for "preoperational appraisal."
pyrophoric	Spontaneously igniting in air; producing sparks by friction.
rad	The unit of absorbed dose equal to 100 ergs/g (0.01 J/kg) in any medium. (See absorbed dose.)
radioactive mixed waste	Radioactive mixed waste is defined as any radioactive waste that is commingled with RCRA-regulated hazardous wastes as defined in 40 CFR Part 261, Subparts C and D.
radiation	Particles or energy emitted from an unstable atom as a result of radioactive decay.
radioactivity	The property of certain nuclides of spontaneously emitting particles or energy or of undergoing spontaneous fission.
radiography	The making of shadow images on photographic emulsion by the action of ionizing radiation. The image is the result of the differential attenuation of the radiation in its passage through the object being radiographed.
radiolysis	Chemical decomposition by the action of radiation.
radionuclide	An unstable nuclide of an element that decays or disintegrates spontaneously, emitting radiation.

radionuclide inventory (nuclide inventory)	A list of the types and quantities of radionuclides in a container or source. Amounts are usually expressed in activity units: curies or curies per unit volume.
Record of Decision (ROD)	The decision document published in the Federal Register by which a Federal department or agency decides on an alternative presented and evaluated through the EIS process.
rem	A special unit for dose equivalent. It is numerically equal to the absorbed dose in rads multiplied by certain modifying factors.
remote-handled waste	Waste that requires shielding in addition to that provided by its container in order to protect those handling it and other people nearby.
repository	A facility for the storage or disposal of radioactive waste.
Resource Conservation and Recovery Act (RCRA)	This Act was designed to provide "cradle to grave" control of hazardous chemical wastes.
retrievable	Storage of radioactive waste in a manner designed for recovery without loss of control or release of radioactivity.
risk	The product of probability and consequence. In this report, the radiological risk of a scenario is the population dose equivalent resulting from that scenario multiplied by the probability that the scenario will actually occur.
risk assessment	A qualitative or quantitative evaluation of the environmental and/or health risk resulting from exposure to a chemical or physical agent; combines exposure assessment results with toxicity assessment results to estimate risk.
roentgen	The special unit of exposure. One roentgen equals 2.58 x 10^{-4} coulomb per kilogram of air.
Rustler Formation	The evaporite beds, including mudstones, of probable Permian age that immediately overlie the Salado Formation in which the WIPP disposal levels are built.
Salado Formation	The Permian age evaporite formation. A geologic waste repository at the Los Mendanos site would be constructed within this formation.

scenario	A particular chain of hypothetical circumstances that could, in principle, release radioactivity or hazardous chemicals from a repository or during a transportation accident.
shaft	A man-hole; either vertical or steeply inclined, that connects the surface with the underground workings of a mine.
shelf	In the ocean, the zone extending from the line of permanent immersion to the depth where there is a marked or rather steep descent to great depths.
source term	The kinds and amounts of radionuclides and/or hazardous chemicals that make up the source of a potential release.
specific activity	Total activity of a given nuclide per gram of a compound, element, or radioactive nuclide.
spent fuel	Nuclear reactor fuel that, through nuclear reactions, has been sufficiently depleted of fissile material to require its removal from the reactor.
Supplement to the Environmental Impact Statement (SEIS)	For purposes of the Waste Isolation Pilot Plant, this SEIS is supplementary information to that provided in the Final Environmental Impact Statement prepared in 1980. This SEIS evaluates the environmental consequences of the proposed action as modified since 1980 in light of new information and assumptions.
sylvite	The mineral, potassium chloride, used as a fertilizer.
syncline	A fold in rocks in which the strata dip inward from both sides toward the axis.
tectonic activity	Movement of the earth's crust such as uplift and subsidence and the associated folding, faulting, and seismicity.
tectonism	The structural behavior of an element of the earth's crust during, or between, major cycles of sedimentation.
Test Phase	A program proposed by DOE to reduce uncertainties asssociated with factors which may affect repository performance and to demonstrated waste handling operations.

transfer cell	An interim area of the waste handling building used to offload TRUPACTS before they are brought into the building and opened.
transmutation	Any process in which a nuclide is transformed into a different nuclide, or more specifically, when transformed into a different element by a nuclear reaction.
transuranic nuclide	A nuclide with an atomic number (number of protons) greater than that of uranium (92). All transuranic nuclides are produced artificially and are radioactive.
transuranic (TRU) waste	TRU waste results primarily from plutonium reprocessing and fabrication as well as research activities from DOE defense installations. It is material contaminated with alpha-emitting radionuclides that are heavier than uranium with half-lives greater than 20 years and in concentrations greater than 100 nanocuries per gram (nCi/g).
TRUPACT	Transuranic Package Transporter.
TRUPACT-II	TRUPACT-II is the package designed to transport contact-handled TRU waste to the WIPP site. It is a cylinder with a flat bottom and a domed top that is transported in the upright position. The major components of the TRUPACT-II are an inner, sealed, stainless steel containment vessel within an outer, sealed, stainless steel containment vessel. Each containment vessel is non-vented and capable of withstanding 50 pounds of pressure per square inch (psi). The inner containment vessel cavity is approximately six feet in diameter and six feet tall, with a capability of transporting fourteen 55-gallon drums, two standard waste boxes, or one box and 7 drums.
unity	One.
upper boundary accident	The worst accident that, by agreement, need be taken into account in devising protective measures.
void volume	The total volume in a matrix not occupied by the matrix material.
TRU waste	See transuranic (TRU) waste.
vuggy	Rock containing small cavities which may or may not be infilled.

Waste Acceptance Criteria (WAC)	The DOE document describing the criteria by which unclassified transuranic waste will be accepted for emplacement at the WIPP and the basis upon which these criteria were established.
Waste Isolation Pilot Plant (WIPP)	The facility near Carlsbad, New Mexico that has been designated to be an experimental and operational site for evaluating disposal capabilities of bedded salt for defense-generated transuranic waste.
waste form	The condition of the waste. This phrase is used to emphasize the physical and chemical properties of the waste.
waste matrix	The material that surrounds and contains the waste and to some extent protects it from being released into the surrounding rock and groundwater. Only material within the canister (or drum or box) that contains the waste is considered part of the waste matrix.

ABBREVIATIONS AND ACRONYMS

AEA	Atomic Energy Act
AEC	U.S. Atomic Energy Commission
AED	aerodynamic-equivalent diameter
AEOC	Alternative Emergency Operations Center
AIC	acceptable daily levels for chronic intake
AIPC	All Indian Pueblo Council
ALARA	as low as reasonably achievable
AMAD	activity median aerodynamic diameter
AMSL	above mean sea level
ANL	Argonne National Laboratory

Abbreviations and Acronyms	AC-1	Add ASWS/C&S - air support weather shield/certification and segregation.

ATSDR	Agency for Toxic Substances and Disease Registry

Abbreviations and Acronyms	AC-1	Add BEIR - Committee on Biological Effects of Radiation.

CCC	WIPP Control Coordination Center
C&C	consultation and cooperation
C of C	certificate of compliance
CEDE	committed effective dose equivalent
CEQ	Council on Environmental Quality
Cf-252	californium-252
CFR	Code of Federal Regulations

ABBREVIATIONS AND ACRONYMS

AEA	Atomic Energy Act
AEC	U.S. Atomic Energy Commission
AED	aerodynamic-equivalent diameter
AEOC	Alternative Emergency Operations Center
AIC	acceptable daily levels for chronic intake
AIPC	All Indian Pueblo Council
ALARA	as low as reasonably achievable
AMAD	activity median aerodynamic diameter
AMSL	above mean sea level
ANL	Argonne National Laboratory
atm	atmosphere
ATSDR	Agency for Toxic Substances and Disease Registry
ATSF	Atchison, Topeka and Santa Fe Railroad
BLM	Bureau of Land Management
CCC	WIPP Control Coordination Center
C&C	consultation and cooperation
C of C	certificate of compliance
CEDE	committed effective dose equivalent
CEQ	Council on Environmental Quality
Cf-252	californium-252
CFR	Code of Federal Regulations

CH	Contact-handled; refers to TRU waste not requiring shielding or specially designed facilities for handling
Ci	curie
Ci/l	curies per liter
cm	centimeter
CO	carbon monoxide
CPFs	carcinogenic potency factors
CTUIR	Confederated Tribes of the Umatilla Indian Reservation
CVSA	Commercial Vehicle Safety Alliance
dB	decibel
DCF	dose conversion factor
DEIS	Draft Environmental Impact Statement
DHLW	Defense High-Level Waste
DOE	U.S. Department of Energy
DOI	U.S. Department of the Interior
DOT	U.S. Department of Transportation
DVM	Distributed Velocity Method
EEG	Environmental Evaluation Group
EID	Environmental Improvement Division
EIS	Environmental Impact Statement
EMP	Ecological Monitoring Program
EP	extractive procedure
EO	Executive Order
EOC	Emergency Operations Center
EPA	U.S. Environmental Protection Agency

ER	emergency response
ERDA	U.S. Energy Research and Development Administration
°F	degrees Fahrenheit
FDA	Food and Drug Administration
FEIS	Final Environmental Impact Statement
FLPMA	Federal Land Policy and Management Act
FSAR	Final Safety Analysis Report
ft	foot
ft^2	square foot
ft^3	cubic foot
g	gram
g/ft^3	grams per cubic foot
g/l	grams per liter
gal	gallon
HEPA	high-efficiency particulate air
HI	hazard index
HSWA	Hazardous and Solid Waste Amendments
H_2S	hydrogen sulfide
IAPI	Office of Intergovernmental Affairs and Public Information
ICRP	International Commission on Radiological Protection
ICV	inner containment vessel
IDB	Integrated Data Base
IDLH	immediate danger to life and health
INEL	Idaho National Engineering Laboratory
ISC	Industrial Source Complex (model)

ISCLT	Industrial Source Complex Long Term (model)
ISCST	Industrial Source Complex Short Term (model)
kg	kilogram
L	liter
LANL	Los Alamos National Laboratory
lb	pound
LCF	latent cancer fatality
LET	linear energy transfer
LLNL	Lawrence Livermore National Laboratory
m^3	cubic meter
mg/kg	milligrams per kilogram
mi	mile
mi^2	square mile
mm	millimeter
MOU	Memorandum of Understanding
mph	miles per hour
mrem/hr	millirem per hour
MSHA	Mining Safety and Health Administration or Mine Safety and Health Act
NA	not applicable
NAS	National Academy of Sciences
NCAI	National Congress of American Indians
nCi/g	nanocuries per gram
NCRP	National Council on Radiation Protection and Measurements
NEFTRAN	network flow and transport code

NEFTRAN	network flow and transport code
NEPA	National Environmental Policy Act of 1969
NMDG&F	New Mexico Department of Game and Fish
NO	nitrogen oxide
NO_2	nitrogen dioxide
NO_x	nitrogen oxides
NRC	U.S. Nuclear Regulatory Commission
NRHP	National Register of Historic Places
NTS	Nevada Test Site
NUPAC	Nuclear Packaging Company
NWPA	Nuclear Waste Policy Act of 1982
NWPAA	Nuclear Waste Policy Act Amendments of 1987
O_3	ozone
OCRWM	Office of Civilian Radioactive Waste Management
ONWI	Office of Nuclear Waste Isolation
ORNL	Oak Ridge National Laboratory
OSHA	Occupational Safety and Health Administration or Occupational Safety and Health Act
PAB	performance assessment brine
PE-Ci	plutonium-equivalent curie
PREPP	Process Experimental Pilot Plant
PSA	Pacific States Alliance
psi	pounds per square inch
psig	pounds per square inch gauge
Pu-238	plutonium-238

Pu-239	plutonium-239
PVC	polyvinyl chloride
QA	Quality Assurance
R	roentgen
R&D	Research and Development
RADTRAN II	A computer model for determining potential radiation doses during transit
RAM	radioactive materials
RBP	radiological baseline program
RCRA	Resource Conservation and Recovery Act
REPS	Regulatory and Environmental Programs Section, Westinghouse
RFP	Rocky Flats Plant
RH	Remote-handled; refers to TRU waste requiring shielding of waste containers or waste-handling facilities
RHMC	Radioactive and Hazardous Materials Committee

Abbreviations and Acronyms AC-6

Add RTR - Real-time x-ray radiography.

RWMC	Radioactive Waste Management Complex
SEIS	Supplemental Environmental Impact Statement
SO_2	sulfur dioxide
SOP	standard operating procedure
SPDV	Site and Preliminary Design Validation
SPHEM	Superfund Public Health Evaluation Manual
SPI	slagging pyrolysis incineration
SRF	Supercompaction and Repackaging Facility
SRP	Savannah River Plant

SS&EP	Safety, Security, and Environmental Protection
SSEB	Southern States Energy Board
STEP	States Training and Educational Program
SWB	standard waste boxes

Abbreviations and Acronyms AC-7

Add SWEPP - Stored Waste Examination Pilot Plant.

TCC	TRANSCOM Control Center
TCE	trichloroethylene
TDEM	time domain electromagnetic
TI	Transport Index
TLV	threshold limit value
TMF	TRUPACT Maintenance Facility
TR	Technical Representative (DOE)
TRANSCOM	Transportation Tracking and Communications System
TRU	transuranic
TRUPACT	Transuranic Package Transporter
TRUPACT-II	Type B Shipping Container
TSA	transuranic storage area
TSP	total suspended particles
TWA	time-weighted average
TWI	TRU Waste and Integration
USC	United States Code (of laws)
USFWS	U.S. Fish and Wildlife Service
vol	volume

Pu-239	plutonium-239
PVC	polyvinyl chloride
QA	Quality Assurance
R	roentgen
R&D	Research and Development
RADTRAN II	A computer model for determining potential radiation doses during transit
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REPS	Regulatory and Environmental Programs Section, Westinghouse
RFP	Rocky Flats Plant
RH	Remote-handled; refers to TRU waste requiring shielding of waste containers or waste-handling facilities
RHMC	Radioactive and Hazardous Materials Committee
ROD	Record of Decision
RWCTF	Radioactive Waste Consultation Task Force
RWMC	Radioactive Waste Management Complex
SEIS	Supplemental Environmental Impact Statement
SO_2	sulfur dioxide
SOP	standard operating procedure
SPDV	Site and Preliminary Design Validation
SPHEM	Superfund Public Health Evaluation Manual
SPI	slagging pyrolysis incineration
SRF	Supercompaction and Repackaging Facility
SRP	Savannah River Plant

SS&EP	Safety, Security, and Environmental Protection
SSEB	Southern States Energy Board
STEP	States Training and Educational Program
SWB	standard waste boxes
SWC	standard waste containers
SWIFT II	Sandia Waste Isolation Flow and Transport Code
TCC	TRANSCOM Control Center
TCE	trichloroethylene
TDEM	time domain electromagnetic
TI	Transport Index
TLV	threshold limit value
TMF	TRUPACT Maintenance Facility
TR	Technical Representative (DOE)
TRANSCOM	Transportation Tracking and Communications System
TRU	transuranic
TRUPACT	Transuranic Package Transporter
TRUPACT-II	Type B Shipping Container
TSA	transuranic storage area
TSP	total suspended particles
TWA	time-weighted average
TWI	TRU Waste and Integration
USC	United States Code (of laws)
USFWS	U.S. Fish and Wildlife Service
vol	volume

W	watts
WAC	Waste Acceptance Criteria
WACCC	Waste Acceptance Criteria Certification Committee
WEC	Westinghouse Electric Corporation
WGA	Western Governors' Association
WHB	waste handling building
WIEB	Western Interstate Energy Board
WIIP	WIPP Integrated Institutional Program Plan
WIPP	Waste Isolation Pilot Plant
yr	year

LIST OF PREPARERS

Those who prepared this draft supplement to the Final Environmental Impact Statement for the Waste Isolation Pilot Plant are identified below.

The overall effort was led by W. John Arthur III, DOE SEIS Project Manager. Assistance was provided to DOE-AL by Advanced Sciences, Inc., and its subcontractors, Roy F. Weston, International Technology, the S. M. Stoller Corporation, and Jacobs Engineering Group. The persons contributing to the SEIS are listed below.

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Section 2	Background: An Overview of WIPP	D. Lechel, R. Hansen, K. Knudtsen, J. McFee, E. Louderbough
Section 3	Description of the Proposed Action and Alternatives	D. Mercer, D. Jones, D. Lechel, K. Knudtsen, E. Louderbough
Section 4	Description of the Existing Environment	S. McBee, C. Comstock, D.Diener
Section 5	Environmental Consequences	S. McBee, C. Comstock, D. Mercer, K. Knudtsen, M. Merritt, D. Diener, S. Beranich, W. McMullan, S. Everette, S. Eagan, S. Kline, L. Adcock
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Section 8	Short-Term Uses and Long-Term Productivity	C. Kennedy, R. Van Vleet
Section 9	Irreversible and Irretrievable Commitments of Resources	C. Kennedy, D. Diener
Section 10	Environmental Regulatory Requirements	R. Hansen

Volume 2 (Appendices)		Principals
Appendix A	Waste Isolation Pilot Plant Waste Acceptance Criteria	S. McBee
Appendix B	Waste Characteristics	S. McBee, W. McMullan
Appendix C	Transportation Emergency Planning	C. Kennedy
Appendix D	Transportation and Transportation-Related Risk Assessment	W. McMullan, S. Eagan, S. Everette, S. Kline, S. Beranich
Appendix E	Permeability Measurements and Brine Inflow Rates	C. Comstock, C. Wood, S. McBee
Appendix F	Radiological Release and Dose Modeling for Permanent Disposal Operations	D. Mercer
Appendix G	Toxicity Profiles, Risk Assessment Methodology, and Models for Chemical Hazards	K. Knudtsen, M. Flowers G. Lage
Appendix H	Public Information and Intergovernmental Affairs	A. Marshall
Appendix I	Methods and Data Used in Long-Term Consequence Analyses	M. Merritt, K. Knudtsen
Appendix J	Bibliography	R. Wardrop
Appendix K	DOE Reading Rooms and Public Libraries	T. Loughead

Brief biographic summaries for the preparers are provided below.

Larry Adcock, Economist, U.S. Department of Energy

PH.D. Economics and Urban/Regional Planning, University of New Mexico, 1983

M.A. Economics, University of New Mexico, 1972
B.A. Economics, University of New Mexico, 1968

Dr. Adcock is a Regional Economist with 20 years experience in regional economic impact analysis and regional econometric model building. His experience includes economic impact analysis for more than a dozen projects. Dr. Adcock provided the socioeconomic component analysis for the WIPP FEIS of 1980. He has directed a university business and economic research agency and served as Cabinet Secretary for Economic Development and Tourism for the State of New Mexico.

Sandra J. Beranich, Staff Scientist, Roy F. Weston, Inc.

B.A. Geology, Southern Illinois University, 1968
M.A. Geography, University of Oregon, 1973

Ms. Beranich has 10 years of experience in environmental document preparation and multidisciplinary studies for evaluation of proposed Federal and private actions on public land, in determining the adequacy of Federal agency and environmental documents, and in coordinating and interfacing Federal land-use planning documents with NEPA requirements. She has coordinated and prepared environmental assessments, developed monitoring and surveillance plans for remedial actions, and coordinated selections for disposal sites.

Charles R. Comstock, R.G. C.E.G., Project Manager, Hydrogeologist, Roy F. Weston, Inc.

B.S. Geology, San Jose State University, 1967
Graduate Studies in Geology, San Jose University, 1972 - 1974
Registered Geologist, State of California
Certified Engineering Geologist, State of California

Mr. Comstock has 14 years of experience in hydrology and engineering geology, primarily related to aquifer contamination assessments, nuclear waste repository siting, nuclear power plant siting and licensing, and groundwater resource investigations. He participated in prominent nuclear waste programs, including the Basalt Waste Isolation Project, the National Waste Terminal Storage Program, and the Uranium Mill Tailings Remedial Action Project.

Richard A. Diener, Wildlife Biologist, Advance Sciences, Inc.

B.S. Zoology, University of Illinois, 1952
M.S. Zoology, University of Arkansas, 1956
Ph.D. Zoology, University of Oklahoma, 1965

Dr. Diener is a biologist with more than 30 years of experience in developing and conducting research in various biological disciplines. These include herpetology, estuarine fishery biology and hydrology, crustacean physiology, and the evaluations of impacts from water-resource development projects on various fishery and wildlife habitat types. He has prepared or participated in a large number of environmental assessments and environmental impact statements.

Steven L. Eagan, Transportation Engineer, S. M. Stoller Corporation

B.S. Civil Engineering, University of New Mexico, 1974
M.S. Civil Engineering, Massachusetts Institute of Tech., 1977
M.A. Public Administration, University of New Mexico, 1984

Mr. Eagan has over fifteen years of experience in the field of transportation systems. He has provided technical assistance on transportation-related issues in nuclear waste management and conducted transportation risk assessment for proposed TRU waste shipments.

Steven E. Everette, Senior Technical Staff, The S. M. Stoller Corporation

B.S. Biology and Chemistry, Western Oregon State College, 1968

Mr. Everette has 17 years experience in transuranic and low-level waste management. He contributed to the WIPP EIS and conducted technology projects for DOE transuranic and low-level waste retrieval, transportation, and confinement. Mr. Everette was a member of the WIPP Waste Acceptance Criteria Committee.

Mary H. Flowers, Environmental Toxicologist, Advanced Sciences Inc.

B.S. Zoology, Ohio State University, 1978
M.S. Environmental Toxicology, University of Arizona, 1981

Ms. Flowers is an Environmental Toxicologist with 7 years of experience in hazardous-material assessments and waste management. She has prepared environmental assessments, and remedial investigation plans. She has prepared public health impact analyses and site characterization for hazardous and mixed-waste sites.

Roger P. Hansen, Senior Staff Consultant/Project Manager, IT Corporation

B.S. Journalism, University of Illinois, 1951
J.D. University of North Carolina, 1962

Mr. Hansen has multidisciplinary background in environmental law, land use and environmental planning, and communications. He has prepared complex permitting documents for major hazardous-waste management facilities. He also conducted and prepared environment assessments and impact statements on nuclear waste respositories. He organized and supervised comprehensive environmental assessments for major mining, energy, and recreation developments, developed methodologies for evaluating and ranking alternative industrial sites according to a set of criteria, and prepared documentation in support of expert testimony in judicial and administrative proceedings. He has served for 6 years as an Adjunct Professor of Environmental Law at the University of Denver College of Law and the Colorado School of Mines.

Dale C. Jones, Principal Project Leader, Roy F. Weston, Inc.

B.S. Mining Engineering, University of Arizona, 1970

Mr. Jones has over 12 years of experience in the preparation of environmental assessments and impact statements. He has prepared and managed the preparation of such documents for uranium mining and reclamation projects with the U.S. Department of the Interior and for the U.S. Department of Energy's Uranium Mill Tailings Remedial Action (UMTRA) Project.

Colburn E. Kennedy, Senior Health and Safety Specialist, Advanced Sciences Inc.

B.S. Occupational Safety and Health, Central Washington University, 1980

Mr. Kennedy is a diversified health and safety specialist with over nine years experience in engineering and human-relations aspects of safety and health. He has expertise in evaluating the safety aspects of engineering designs and providing safety management oversight.

Stephen C. Kline, Technical Staff, S. M. Stoller Corporation

B.S. Mechanical Engineering, Loyola, 1970
University of Los Angeles
M.S. Engineering, University of California at Los Angeles, 1974

Mr. Kline is a registered professional with 16 years of experience in radioactive-waste management and nuclear power generation. His areas of expertise include the development and implementation of long-range plans for waste management, disposal, and transportation operations and risk management for radioactive-waste transportation.

Karen Knudtsen, Project Scientist, IT Corporation

B.S. Soil Science, Ohio State University, 1977
M.S. Soil Chemistry, University of Florida, 1983

Ms. Knudtsen is a soil/environmental chemist with 10 years experience in solid- and hazardous-waste management and environmental assessment. Her experience includes the evaluation of hazardous and radioactive mixed-waste characteristics and mechanisms of contaminant transport in the environment, the preparation of regulatory summaries, the development of technical positions regarding RCRA and CERCLA regulatory compliance and permitting assistance for hazardous-waste facilities.

Gary L. Lage, Project Director/Toxicologist, Roy F. Weston, Inc.

B.S. Pharmacology, Drake University, 1963
M.S. Pharmacology, Drake University, 1965
Ph.D Pharmacology, University of Iowa, 1987

Dr. Lage has over 20 years experience in all phases of toxicology and associated assessment of chemical risk. He was heavily involved in the academic development of toxicology as a scientific discipline through academic appointments at the University of Kansas and the University of Wisconsin. He served as Project Director/Senior Scientist for several major Health Risk Assessment programs for hazardous waste remedial action programs and for proposed hazardous waste incinerators. In addition, Dr. Lage has 20 years experience in toxicological research aimed at identifying the role of altered chemical disposition in relation to the ultimate toxic effect. This mechanistic research approach has been funded by several Federal agencies and national foundations.

David J. Lechel, Project Director, Roy F. Weston, Inc.

B.S. Fisheries Biology, Michigan State, 1972
M.S. Fisheries Biology, Michigan State, 1974

Mr Lechel has over 15 years of experience in project management of multidisciplinary environmental studies, regulatory analysis, and environmental site monitoring. He has been responsible for the design, conduct, management and report preparation for extensive environmental assessments of radioactive and mixed-waste disposal sites, hazardous/toxic waste sites, proposed coal mines, power plants, and waste water treatment facilities.

Ellen T. Louderbough, Environmental Scientist/Ecologist, IT Corporation

B.S. Nursing, Skidmore College, 1968
M.S. Biology, University of New Mexico, 1976
Ph.D Biology, University of New Mexico, 1983

Dr. Louderbough is an ecologist and an environmental scientist specializing in the regulatory issues of waste management and environmental assessment. Her field experience as an ecologist includes the direction of quarterly soil surveys to assess the extent of salt deposition at the WIPP site and a survey of shale-derived soils to study the process of vegetation-soil interactions. She has comprehensive knowledge of RCRA regulations and the NEPA documentation process relative to issues dealing with hazardous and mixed waste.

Tracey Loughead, Public Information Specialist, Jacobs Engineering Group, Inc.

B.A. Psychology, Bucknell University, 1979

Ms. Loughead has extensive experience writing and coordinating press releases, writing, coordinating, and disseminating public information documents, and coordinating public meeting and hearings. She has also managed public information mail list databases.

Ann Marshall, Manager of Community Relations, Advanced Sciences, Inc.

B.A. English, University of Colorado, 1964
M.P.S. Communications Arts, Cornell University, 1976

Ms. Marshall has 20 years of public involvement activities. She has worked on a variety of hazardous-waste management projects which were part of programs including: Superfund, Resource Conservation, and Recovery Act (RCRA), Chemical Emergency Preparedness, and Department of Energy Installation Restoration Program.

John N. McFee, Senior Project Engineer, IT Corporation

B.S. Chemical Engineering, Clarkson College of Technology, 1961
Nuclear Power Engineering School, 1974
Idaho National Engineering Laboratory

Mr. McFee is a chemical engineer with 22 years of experience in chemical synthesis, energy recovery, and waste management process design and development. Recent projects concerned incineration of hazardous and radioactive wastes.

William H. McMullan, Manager, The S. M. Stoller Corporation

B.S. Engineering Mechanics, U.S. Air Force Academy, 1972
M.S. Metallurgy, Columbia University, 1973
M.A. Business Management, NM Highlands University, 1977

Mr. McMullan has over 15 years of experience in government research and development projects, transuranic waste management, high-level waste management, facility planning, NEPA compliance and construction, and project management. Mr. McMullen has been responsible for developing NEPA strategy and compliance options for buried TRU waste, preparing long-range waste management master plans, developing options for optimizing costs and schedules of program elements to achieve permanent disposal of contact-handled, remote-handled, special case and buried TRU contaminated wastes. He has also been responsible for assessing specific and cumulative risks of transporting TRU wastes from generating and storage sites, and coordinating the efforts of TRU-waste generating sites to implement technology for waste volume reduction.

Sarah Mount McBee, Geotechnical Engineer, Advanced Sciences Inc.

B.S. Geology, Southmost Missouri State University, 1976
B.S. Geological Engineering, University of Missouri-Rolla, 1978
M.S. Geological Engineering, University of Missouri-Rolla, 1982

Ms. Mc Bee is an environmental and geotechnical engineer with 10 years of experience in program management, environmental engineering, and geotechnical engineering. She has managed and participated in Remedial Investigations and Feasibility Studies for more than 30 hazardous waste sites. She has prepared Environmental Assessments and RCRA Part B applications.

Daryl D. Mercer, Senior Project Scientist, IT Corporation

B.S. Chemistry and Mathematics, Northwest Missouri State University, 1967
M.S. Public Health, Radiological Hygiene, University of North Carolina, 1973

Mr. Mercer has 18 years of experience in the nuclear industry, with emphasis on health physics, risk analysis, nuclear facility design and construction, and environmental protection, He has provided expert inspection and has reviewed numerous radiological and environmental operations and facilities, developed safety standards and criteria, and utilized his experience and knowledge to establish and conduct radiological and environmental surveillance programs. He has supervised technical personnel and ensured the efficient execution of an operational health physics oversight program and developed and implemented research projects and programs to resolve complex radiological and environmental issues.

Melvin L. Merritt, Principal Scientist, Advanced Sciences. Inc.

B.S. Physics, California Institute of Technology, 1943
Ph.D. Physics, California Institute of Technology, 1950

Dr. Merritt has 38 years of experience in nuclear weapons effects, weapons test safety, and environmental impact assessment. Dr. Merritt has prepared for EAs and EISs involved with operating a national laboratory identifying sites for conducting nuclear tests, WIPP, and uranium mill tailings remediation. He was a member of an NAS subcommittee on fallout and co-edited and authored numerous technical and scientific articles.

Rick J. Van Vleet, Nuclear Engineer, Advanced Sciences, Inc.

B.S. Nuclear Engineering, Kansas State University, 1981
Ph.D. Engineering, Kansas State University, 1985

Dr. Van Vleet is an engineer with 4 years experience in radionuclide transport in saturated media, computer-code verification and benchmarking, model validation, and the preparation of safety analysis reports.

Rita A. Wardrop, Lead Editor, Advanced Sciences Inc.

B.A. English, University of New Mexico, 1988

Ms. Wardrop is a technical writer/editor with experience in technical report production, article preparation, general research, editing, and writing.

Craig J. Wood, P.G., Project Geologist, Roy F. Weston, Inc.

B.S. Geology, Eastern New Mexico University, 1982
Professional Geology Registration State of Florida

Mr. Wood has 7 years of experience as a geologist and a hydrogeologist in the design, implementation, and evaluation of programs to evaluate soils, groundwater, and hydrogeologic and hydrodynamic conditions as they apply to hazardous-waste management. He has coordinated all aspects of technical projects and supervised from project definition, data collection and evaluation, to final report writing.

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